HAWAIIAN MARINE SHELLS

The endemic Hawaiian cowries. Top row: *Cypraea rashleighana*, length 27 mm; *C. gaskoini*, length 15 mm; *C. ostergaardi*, length 12 mm. Second row: *C. semiplota*, length 16 mm, two forms; *C. mauiensis*, length 13 mm. Third row: *C. granulata*, length 24 mm. Bottom row: *C. sulcidentata*, length 35 mm; *C. tessellata*, length 33 mm.

HAWAIIAN MARINE SHELLS

REEF AND SHORE FAUNA OF HAWAII

Section 4: Mollusca

E. ALISON KAY

Bernice P. Bishop Museum Special Publication 64(4)

Bishop Museum Press

Honolulu, Hawaii

PRINTING OF THIS BOOK was made possible by partial financial support from the Charles H. and Margaret B. Edmondson Trust; the Institute of Museum Services, U. S. Department of Health, Education, and Welfare; Pacific Resources, Inc.; and Parsons Hawaii. To each of these the Trustees of Bishop Museum wish to express their sincere appreciation.

Library of Congress Catalog Card No. 78-73430
ISBN 0-910240-26-4
ISSN 0067-6179

Dr. Edward C. Creutz, Director
Genevieve A. Highland, Editor
Sadie J. Doyle, Associate Editor

ALOHA

Charles Howard Edmondson

Jens Mathias Ostergaard

Ditlev Thaanum

Note on the Series

REEF AND SHORE FAUNA OF HAWAII

THIS REVISION of the original single volume edition of this work — published by Bishop Museum in 1933, with a revised edition in 1946 — is dedicated to the author of the original work, Charles Howard Edmondson (1876-1970).

Instead of a single book, the vast increase in information regarding the Hawaiian and Indo-Pacific marine fauna has required the revised edition to be divided into several sections, which will be published separately. Except for *Section 1: Protozoa through Ctenophora*, which was published by the Museum in 1977, the various groups of invertebrates are scheduled to appear in the following manner, but not necessarily in the order given below.

Section 2: Platyhelminthes, Nemertina, Aschelminthes, Ecto-Entoprocta, Brachiopoda, Phoronida

Section 3: Sipuncula, Echiura, Annelida

Section 4: Mollusca

Section 5: Arthropoda

Section 6: Echinodermata, Chaetognatha, Hemichordata, Chordata (excluding Vertebrates)

All sections are the result of more than one contributing author except for the present volume on Mollusca, which was written in its entirety by Dr. E. Alison Kay of the University of Hawaii. The remaining volumes are being edited by Drs. Dennis M. Devaney of Bishop Museum and Lucius G. Eldredge of the University of Guam.

DENNIS M. DEVANEY

B. P. Bishop Museum
Honolulu, Hawaii

January, 1979

CONTENTS

PREFACE

DESPITE THE FACT that the marine shells of the tropical Indo-West Pacific are among the most spectacular and varied in the world, there are few references which treat comprehensively of the molluscan fauna of specific island groups within the compass of that region. It is the aim of this work to fill that lacuna, albeit this study of the marine mollusks of the Hawaiian Islands is that of an area peripheral to and isolated from the presumed center of origin of the Indo-West Pacific fauna in the Indo-Malaysian archipelago. To the biogeographer and evolutionist, however, the mollusks of Hawaii have special meaning, for they represent the most isolated and attenuate fauna in the Pacific. It is hoped, therefore, that this work will serve not only as a manual for conchologists and other biologists who require a ready source of taxonomic information about Pacific mollusks, but also as a guide for biogeographers and amateur collectors interested in the insular biotas of the Indo-West Pacific.

In this work the main attention is focused on the neritic mollusks of the Hawaiian Islands, those occurring to depths of 50 m, or SCUBA diving depths. The arrangement is systematic down to family and subfamily; within these groups genera and species are arranged alphabetically. Infraspecific categories are omitted except where their use appears meaningful. Synonymies are limited to references to species recorded from the Hawaiian Islands, and only the first use of a name is recorded. Except for references from Jay's *Catalogue* (Jay, 1828, 1839), from which many names have been utilized, catalogue references have not been included because of the difficulties involved in identification.

The most formidable of all tasks that I faced in the preparation of this work has been the taxonomic treatment of species. In an attempt to minimize the historical complexities of Indo-West Pacific molluscan taxonomy, primary conchological collections in Europe, the United States, and Australia have been consulted for taxonomic information, and many of the names used are those for which I have actually seen type material.

The historical complexities of taxonomy are compounded by another factor, that of the insular nature of the material. Islands impart peculiar stamps on their biotas; insular plants and animals are not always "typical" representatives of widespread populations; the biota may be disharmonic; and peculiar insular environmental conditions may variously affect the flora and fauna. We know little of the effects of isolation on marine species, less of the effects of environment. To minimize these complexities I have utilized many names originally described from the Hawaiian Islands, hoping thereby to avoid erroneous interpretations which arise from the indiscriminate use of well-known names founded on inaccessible or inadequate type material.

ACKNOWLEDGMENTS

The late Ditlev Thaanum dreamt of a comprehensive work on the Hawaiian marine mollusks long before I was born. If this, in even small measure, is a fulfillment of his dream, its purpose will have been achieved.

The collections of Bernice P. Bishop Museum, Honolulu, Hawaii, have served as a base for this study because they provide the greatest single source of information on the variety of species and their distribution in the Hawaiian archipelago now available. Most of the biological information on supratidal and intertidal forms stems from my own collecting activities during the past thirty years. For information on those mollusks occurring at depths of from 3 to 50 m, Dr. C. M. Burgess, Mr. Ellis Cross, Mr. and Mrs. A. M. Harrison, Mrs. Wayne Gagné (Betsy Harrison), and Mr. C. S. Weaver have been especially helpful. The data on the deep-dwelling mollusks are based on the *Albatross* collections of 1899 and 1901 (now in the U. S. National Museum), and the more recent results of dredging activities of the *Pele*, owned by the late Mrs. Mariel King, the *Teritu* and *Valiant Maid* of the University of Hawaii, and the dredge spoils studies conducted by the U. S. Army Corps of Engineers (1977-1978).

I am indebted to a host of collectors who have made their collections available to me: Mr. and Mrs. James Andrus, Dr. C. M. Burgess, Mr. E. R. Cross, Mr. and Mrs. George Donner, Mr. John Earle, Mr. and Mrs. A. M. Harrison, Mrs. Wayne Gagné, Mrs. Olive Schoenberg, Mr. Richard Salisbury, and Mr. C. S. Weaver. Another patient group of people has read and re-read sections of the manuscript: Mrs. Danielle B. Fellows, Mrs. Arch Harrison, Mrs. Jane Taylor, and Mrs. Dorothy Wendt. Still others have given freely of their specialized knowledge of groups of the mollusks: Mrs. Jean Cate, Mr. Norman Tebble and Mr. Walter O. Cernohorsky worked on the mitrid section initially; Dr. Barry Wilson reviewed the mytilids and cardiids; the late Dr. George Radwin reviewed the muricaceans and columbellids; Mrs. Twila Bratcher discussed the terebrid section; Dr. Richard S. Houbrick saw the cerithid chapter; Dr. Thomas Waller saw the pectinid chapter; Dr. Winston Ponder devoted long hours to discussing micromollusks with me; Drs. Michael G. Hadfield and Marilyn Dunlap-Switzer read the opisthobranch section; and Dr. Anders Warén gave me advice on the Eulimidae.

The curators and section heads of museums throughout the world have also contributed immeasurably to this work by way of their hospitality: Mr. Norman Tebble, formerly of the British Museum (Natural History); Mr. John Peake and Dr. John Taylor of the British Museum (Natural History); Dr. Harald Rehder of the U.S. National Museum, to whom I am especially grateful for the loan of the Dall manuscript; Dr. Joseph Rosewater of the U.S. National Museum; Dr. Tucker Abbott, formerly of the Delaware Museum; Dr. Robert Robertson and Dr. George Davis of the Academy of Natural Sciences, Philadelphia; Mr. Peter Dance, formerly of the University Museum, Manchester, and the National Museum of Wales, Cardiff; Dr. Donald McMichael, formerly of the Australian Museum, Sydney; Dr. Charles Pettitt of the University Museum, Manchester; Dr. Winston Ponder, the Australian Museum, Sydney; Mrs. J. Hope Black of the National Museum of Victoria; Dr. W. Adam, formerly of the Musée Royale d'Histoire Naturelle, Brussels; and Dr. J. Gaillard and Mlle. Françoise Danrigal of the Museum d'Histoire Naturelle, Paris.

For untold hours of tedious typing and retyping, I am indebted to Mrs. Barbara Hoshida, without whose patience and encouragement the manuscript would never have been completed. I also thank Dr. Jane B. Taylor, Mrs. Sue Takemoto, and Mrs. Sandi Shimabukuro for their help with the drawings; Miss Regina Kawamoto for her pictures and drawings; Mr. C. S. Weaver, Mrs. Olive Schoenberg, Dr. S. A. Reed, Dr. W. van Heukelm, Dr. Dale Sarver, Mr. Scott Johnson, Mr. C. N. Cate, and Dr. Jane B. Taylor for use of some of their pictures; and the personnel of the Hawaii Institute of Marine Biology and the Pacific Biomedical Research Center for use of their photographic facilities.

E.A.K.

Honolulu, Hawaii
October, 1978

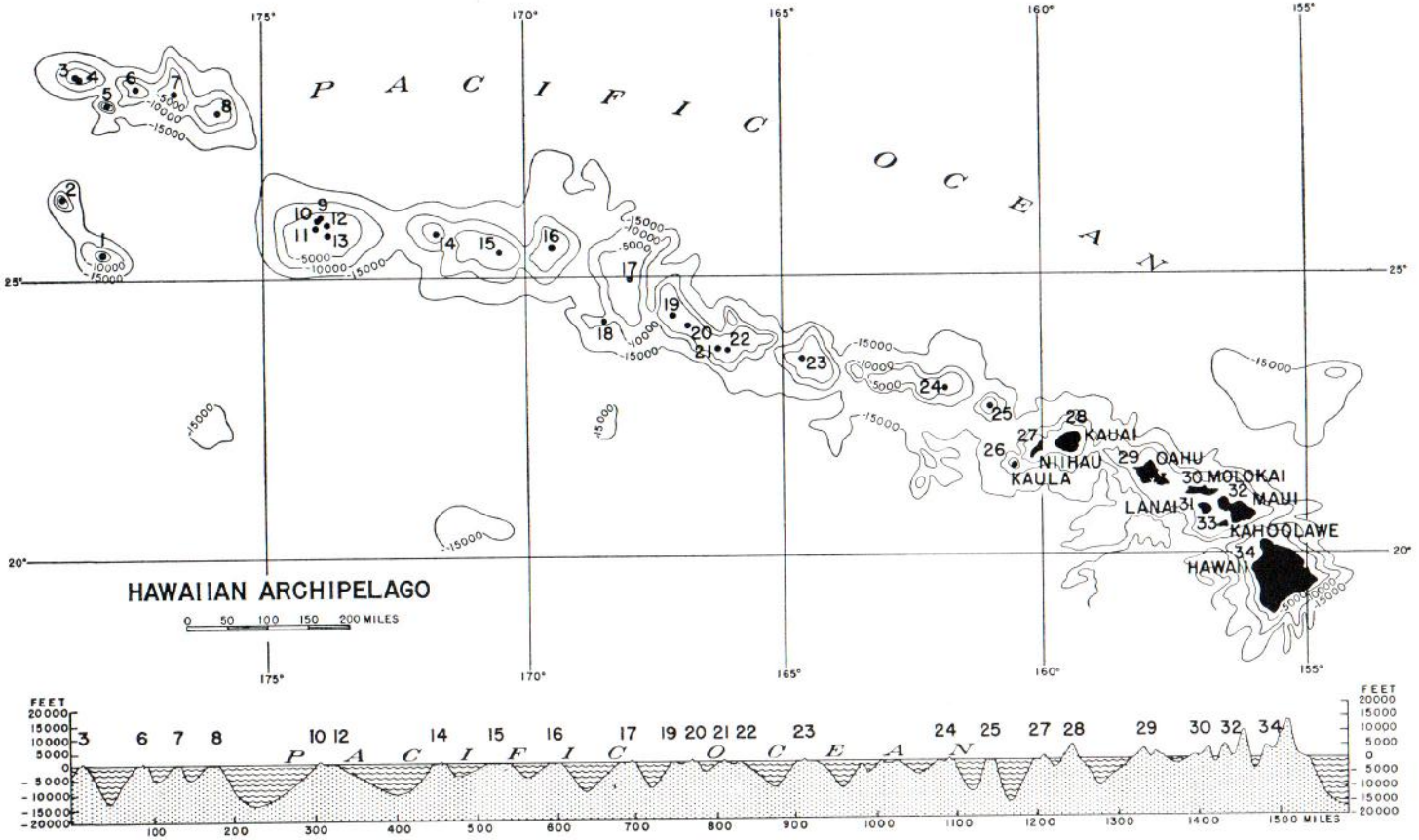


Figure 1.—Map and profile of the Hawaiian Islands showing the submarine contours in feet. 1. Unnamed shoal; 2. Bensaleux Reef; 3. Kure or Ocean; 4. Green; 5. Nero Bank; 6. Midway; 7. Gambia Shoal; 8. Pearl and Hermes Reef; 9. Lisianski; 10. Fisher Reef; 11. Minor Reef; 12. Neva Shoal; 13. Springbank Reef; 14. Laysan; 15. Maro (Dowsett) Reef; 16. Raita Bank; 17. Gardner Pinnacles; 18. Two Brothers Reef; 19. St. Rogatien Bank; 20. Brooks Banks; 21. La Perouse Pinnacle; 22. French Frigate Shoal; 23. Necker; 24. Nihoa; 25. Unnamed shoal; 26. Kaula; 27. Niihau; 28. Kauai; 29. Oahu; 30. Molokai; 31. Lanai; 32. Maui; 33. Kahoolawe; 34. Hawaii. (After Stearns, 1946, in E. C. Zimmerman, 1948. Courtesy University Press of Hawaii and the U. S. Geological Survey.)

INTRODUCTION

A GENERAL ACCOUNT OF THE HAWAIIAN ISLANDS

THE HAWAIIAN ISLANDS comprise a complex of land forms in the Pacific Ocean, extending in a narrow arc for 2,400 km (1,600 miles) from west-north-west between 154°40′ to 171°71′ W longitude and 28°15′ and 18°54′ N latitude (see Fig. 1). Surrounded by deep water, the islands are 2,000 to 2,500 miles distant from Japan, the Aleutian Islands, and North America, and 1,200 miles north and 450 miles east, respectively, of the atolls of Wake and Johnston. The archipelago consists of about 20 land forms, of which the eight southeastern volcanic islands form 99 percent of the land area and are distinguished as the windward group, and the ten westernmost atolls, shoals, reefs, and basaltic remnants are termed the leeward islands.

Each of the Hawaiian Islands began as one or more shield volcanoes built from the depths of the sea by flow upon flow of basaltic lava. The oldest of these volcanoes are to the northwest where the volcanic characteristics of the atolls of Kure, Midway, and Pearl and Hermes Reef lie buried beneath thick caps of coral reef. The youngest of the volcanoes are on Hawaii at the southeast where active craters still spew forth masses of molten lava.

The Hawaiian volcanoes may have begun to emerge from the sea in the Cretaceous, 30,000,000 years ago (Menard and Hamilton, 1963). Dating of Midway basaltic lavas obtained from cores drilled as deep as 420 m through coral reef indicates that Midway's basaltic lavas were perhaps above the sea prior to the Miocene, 20,000,000 years ago (Ladd and others, 1967). Fossil corals from a 500 m terrace southwest of Oahu indicate a probable Miocene age (Menard, Allison, and Durham, 1962). The present topographical features of the windward islands are Pliocene and Recent, but shoreline platforms, wave-cut benches, and raised coral reefs on Oahu, Maui, and Lanai reflect a long history of shore formation during the Pleistocene (Stearns, 1966). Fluctuations of sea level associated with Pleistocene glacier formation and melting are suggested to have caused the Oahu shorelines to change from 84 m above to 100 m below present sea level.

SHORELINES

The island complex includes not only land forms of a variety of ages, but shorelines of a variety of types (see Fig. 2). Among the leeward islands, Kure, Midway, and Pearl and Hermes Reef are typical atolls, consisting of nearly circular reef platforms enclosing lagoons. Gardner Pinnacles, Necker, and Nihoa are volcanic

remnants of once grander islands which now consist of high, sheer cliffs at the interface between land and sea. The islands of the windward group, except for Hawaii, have coastlines composed of coastal sea cliffs reaching as high as 330 m above sea level, sea-level basalt shorelines, calcareous solution and water-leveled benches, sandy beaches, and fringing reefs. The broadly lobate coast of Hawaii Island is of basalt, with little calcareous sand beach and with a single area of fringing reef.

Basalt shorelines are so diverse that it is difficult to characterize them. They are distinguished by the dull, black color and great density of the substrate, but they differ one from another in elevation, orientation, and topography.

The horizontal faces of ancient lava flows form benches at or just above mean tide level along some sections of the shoreline, especially on the windward coasts of Kauai and Oahu, and along most of the coastline of Hawaii. The benches vary in width from less than 10 m to more than 100 m in width. The frontal face is encrusted by a veneer of pink coralline algae (*Porolithon* spp.), stubby growths of the frondose alga *Sargassum*, and they may be honeycombed by borings of the sea urchin *Echinometra*. Shoreward crevices and depressions in the basalt substrate form pools in which the physical conditions vary with exposure. Pools farthest from the sea undergo striking variations in temperature and salinity; those at the seaward edge exhibit marine conditions. The most exposed pools may have a sand substrate bound with blue-green algae and their main inhabitants are mollusks, grapsid crabs, a goby, and a blenny. Seaward pools have dense algal turf and a variety of worms, mollusks, crustaceans, and echinoderms.

Other areas of the shoreline are characterized from shore to depths of about 15 m by boulders which are strewn over the sea floor. The seaward faces of the boulders, like the benches, are encrusted with algae and corals, and are the habitats for a variety of worms, mollusks, and sea urchins. This type of coastline is especially subject to strong surge (Hobson, 1974).

Hawaiian reefs are neither so spectacularly developed nor so diverse as are the reefs of other Pacific islands, a circumstance associated with the location of the islands at the northern edge of the coral reef zone of tropical and subtropical seas, and therefore near the low temperature extreme to which corals are sensitive. Fourteen coral genera (38 species) have been recorded from the windward islands (Vaughan, 1907; Maragos, 1972) with nine genera only from Midway and Kure (Gross and others, 1969), figures which may be compared with the 52 genera recorded from the Marshall Islands (Wells, 1954), and the 30 genera (70 species) known from Fanning Island in the Line Islands (Maragos, 1974).

Despite the relative scarcity of coral genera, intertidal reef development is a characteristic feature of Hawaiian shorelines, but the reefs which fringe the shorelines of the windward islands are composed largely of coralline algae (Pollock, 1928; Littler, 1973). Littler (1973) has demonstrated that on the fringing reef at Waikiki, Oahu, coelenterate corals are relatively unimportant in the over-all fringing reef habitat, with crustose coralline algae exceeding all other organisms as the dominant reef builders.

The fringing reefs (Fig. 2 A) of the windward and protected coasts of Oahu and Kauai are wide, shallow platforms extending as much as 500 m seaward from shore; those of the north and west coasts are more irregular and are deeper. The shoreward portions of the reef flats are characterized by a predominantly sandy substrate interspersed with patches of living coral, coralline algae, coral rubble, and frondose

A

B

C

D

E

F

Figure 2.—Shorelines of the Hawaiian Islands. A. Fringing reef, Diamond Head, Oahu. B. Sandy beach, Kahuku, Oahu. C. Tide pools, Keaau, Hawaii. D. Tide pool, Honaunau, Hawaii. E. Solution bench, Maili Point, Oahu. F. Anchialine pool, Anaehoomalu, Hawaii.

algae such as *Sargassum* and *Acanthophora*. The reef flat is typically subtidal and variable in depth from less than 1 m to more than 3 m below mean sea level. The outer edge of the reef is about 1 m below low tide and often densely fringed with *Sargassum*. The seaward edge (algal ridge of authors) is characteristically somewhat higher than the inner portion, usually awash at low tide and encrusted with coralline algae (Littler, 1973). The outer wall is steep, descending to deep water where at depths of 10 to 50 m it is characterized by vigorous coral growth.

Calcareous shoreline platforms, termed solution benches (Wentworth, 1938; 1939), are as conspicuous as reefs in forming a dominant shoreline feature of the windward islands (Fig. 2 E). On Oahu this type of shoreline comprises 52 miles or 31 percent of the coastline (Wentworth, 1938). Topographically solution benches resemble atoll reef flats, consisting of sea-level platforms extending from 1 to 30 m seaward. The benches are separated from shore by a raised, sharply pitted limestone zone and a nip (Fig. 2 E). Seaward of the nip the flat-topped surface is densely matted with algal turf. At the sloping outer edge, calcareous algae, and, to a lesser extent, corals, contribute to the structure of the bench.

The sandy shorelines of the windward islands are usually stretches of low, sloping beach backed by a wall or raised coral platform (Fig. 2 B). The most extensive development of long beaches occurs on Kauai, with shorter stretches characteristic of other islands except for Hawaii, where only a few, somewhat transitory beaches are known. The beaches are formed mainly of detrital carbonate grains; those on Hawaii are often basaltic. On many beaches there is a line of beach rock at the base or midbeach. The sand behind the rock exposure is usually devoid of life except for the crab *Ocypode*.

OFFSHORE WATERS

The offshore waters surrounding the Hawaiian Islands range in depth from the intertidal to 800 m within a narrow band of shelf. The central islands of Kauai, Oahu, Maui, Molokai, and Lanai surmount a common ridge which rises abruptly from the Pacific floor from 1,000 m to about 100 m. A conspicuous break in slope at 900 m marks the outer edges of extensive drowned terraces; deeper terraces are, however, also known down to 2,000 m.

Corals extend subtidally to depths of about 100 m. Spectacular coral development occurs on submarine surfaces of recent lava flows off the leeward coast of Hawaii from Kawaihae to Kapoho, where corals form dense communities at depths of from 1 to 22 m. Other areas of coral development occur at similar depths on the surface of the 1790 lava flow at La Perouse Bay, Maui, off the islet of Molokini in the Molokai channel, and at depths of from 12 to 30 m on Penguin Bank off Molokai.

WINDS, CURRENTS, WAVES, AND TEMPERATURES

The Hawaiian meteorological regime is dominated by the northeast trade winds, the trade-wind zone moving north and south with the sun. The zone reaches its northernmost point from May through September when trade winds are prevalent from 80 to 95 percent of the time. From October through April, the center of the trade-wind zone is south of Hawaii, but the trade winds continue to blow from 65 to 80 percent of

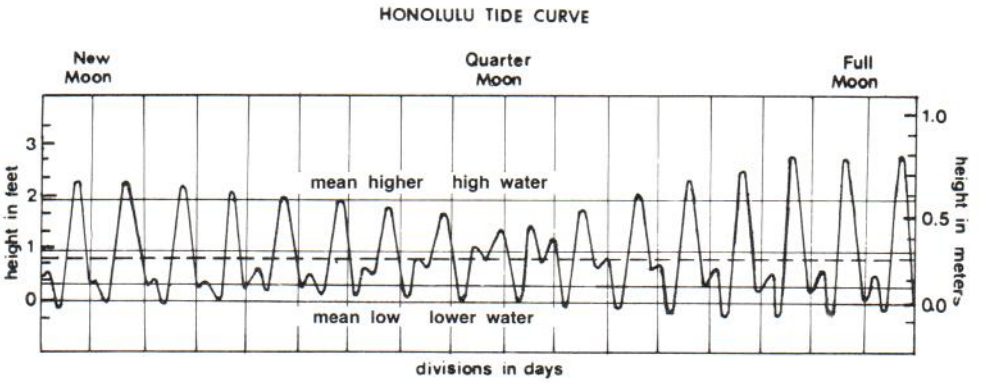


Figure 3.—Tide curves for Honolulu, Oahu. (From *Atlas of Hawaii*, p. 52, Department of Geography, Univ. Hawaii, 1973, by permission of University Press of Hawaii.)

the time. During this period light and variable winds are interspersed with Kona storms or low pressure areas (see Blumenstock and Price, 1972, for a detailed account).

The major current systems surrounding the Hawaiian Islands are the North Equatorial Current and the North Pacific Current. North Pacific Current waters, the surface waters of which have a salinity in excess of 34.80 o/oo, bathe the islands and extend on the surface to the north and west of the island chain. Surface flow of water is, however, subject to considerable variability in direction and velocity. During the winter (December to May) water arrives from the east or southeast and flows roughly parallel to the islands; during the summer (July to October) the dominant approach is from the northeast. Maximum current velocities occur at high and low tide, in contrast to continental areas where maximum velocities usually occur at the time of rising and falling (traditional flood and ebb) of the tide (Laevastu and others, 1964).

Tides are of the mixed type, diurnal and semidiurnal, with the semidiurnal component predominating (Fig. 3). Because of the progressive change in phase difference between the two tides, high tides and low tides are about 50 minutes later each day. Maximum tidal range is about 1 m.

While tidal range is sufficiently extensive to determine the physical characteristics of sea-level shore platforms and fringing reefs, wave action is an even more conspicuous feature in raising the effective height of the sea along island shorelines. The most persistent wave type along eastern shores is that associated with the northeast trade winds which, from May to September, generate waves from 1 to 3.5 m in height with periods of from 5 to 8 seconds. Higher waves (1.5 to 4 m with periods of from 10 to 17 seconds) are associated with the North Pacific swell and Kona storm waves from October to April. These wave types are associated with low pressure areas generated in the north and south, respectively. The southern and lee shores of the islands are especially subject to long, low waves (0.5 to 1 m with periods of 14 to 23 seconds) of the southern swell during the summer months. Inshore, because of shallow water and friction, wave heights may reach 4 or 5 m. One result of wave action is that tide pools or benches exposed at a 0 tide in April may be completely awash at the same tide in January.

Surface water temperatures are fairly stable, but there are noticeable differences from north to south. Among the windward islands water temperatures average 24.6° C

with a maximum of 26.8° C in summer and a minimum of 22.4° C in winter. At Midway the mean sea surface temperature is 23.1° C with a maximum of 26.9° C in August and a minimum of 19.2° C in February (Gross and others, 1969). The greatest temperature range occurs at depths between 200 and 300 m where the thermocline is usually found.

ECOLOGY OF HAWAIIAN MARINE MOLLUSKS

The biotic assemblages of shorelines are traditionally described in terms of patterns of occurrence which are associated with tidal and wave action. These patterns have been variously divided and subdivided into zones, fringes, horizons, belts, etc. Hawaiian marine ecosystems, for example, were subdivided by Gosline and Brock (1960) into four regions, the suprasurge, surge, and subsurge zones and reef protected areas. A more widely used scheme is the tripartite zonal arrangement proposed by Stephenson and Stephenson (1949) and variously modified by Southward (1958), Lewis (1964), and J. D. Taylor (1968). This scheme can be readily adapted to Hawaiian shorelines.

In the tripartite scheme, the highest zone of the shoreline, the supralittoral or supraspray zone, lies above the upper limit of waves and tides, and is an area where marine and terrestrial organisms intermingle. Landward of the supralittoral zone lies a band of maritime vegetation, naupaka *(Scaevola),* hau *(Hibiscus),* sea heliotrope *(Messerschmidia),* and *Panicum* in Hawaii (see Kay, 1977). Seaward lies an area varying in width and characteristics depending on exposure. This is the eulittoral zone which is also sometimes appropriately termed the intertidal because it effectively lies between the reach of waves and tides and the 0.0 tide level. The eulittoral is occupied by marine organisms which are for the most part adapted to alternating conditions of submersion and emersion. Below the 0.0 tide level, where organisms are only rarely emersed or where they spend all their lives beneath the surface of the water is the sublittoral zone.

In Hawaii, where tidal range is restricted, wave action often effectively scours intertidal pools and submerges solution benches, and zonation patterns may not be quite so clear-cut as they are on rocky shorelines at higher latitudes. Differences in wave action on windward and leeward shorelines also affect zonation patterns: the eulittoral zone, for example, may be almost entirely obliterated on low energy shorelines such as are found at Maalaea Bay, Maui and at Puako, Hawaii. And, while zonal divisions on rocky shores are quite sharp, those on sand beaches are far less distinct.

SUPRALITTORAL ZONE

Three genera of marine pulmonates *(Melampus, Laemodonta, Pedipes)* and one prosobranch *(Assiminea)* are found in the supralittoral zone. These mollusks occur in patchy colonies where there are boulders or broken limestone and conditions of high humidity. The colonies are often mixed, with *Melampus, Laemodonta,* and *Assiminea* occurring most frequently. Only occasional colonies of a single species are found. All presumably have veliger larvae, although the stages may be somewhat suppressed, and thus all are tied to the sea by their mode of reproduction.

Seaward of the pulmonate colonies but still above the reach of either tides or waves, the shoreline is dominated by two species of littorines, *Littorina pintado* and *Nodilittorina picta*. Densities of littorines can be very high: Struhsaker (1968) estimated populations of 800,000 and 600,000 of each species respectively on a bench of approximately 860 m^2. The two species overlap in the major portions of their zones, but *L. pintado* extends farther shoreward than *N. picta* which extends farther seaward. Significant seasonal differences in the relative abundance of the two species is associated with variations in the species' responses to environmental extremes: *L. pintado* is more tolerant of higher temperatures than *N. picta*, which is tolerant of more wave splash (Struhsaker, 1968). There are two forms of *N. picta:* a smooth form found on lower water-leveled benches; and a granulated form on higher angled benches. A third littorine, *Peasiella tantilla*, sometimes occurs with the others but is more often found in crevices and spray-filled pools than are the other two species. Littorines reproduce by pelagic larvae, and, like the pulmonates, are tied to the sea by their mode of reproduction.

Seaward of the littorines on rocky shorelines, the black nerite or pipipi, *Nerita picea*, is the most noticeable mollusk. It, too, remains above the reach of the highest tides, moving up and down the shore with the tides. The nerites are succeeded by the naked pulmonate *Onchidium verraculatum*, the cephalaspid opisthobranch, *Smaragdinella calyculata*, and by a narrow zone of the shelled pulmonate limpet, *Siphonaria normalis*. *Siphonaria* may remain in situ where they are covered by the incoming sea at high tides and thus are at the landward edge of the eulittoral zone. A peculiar element in these assemblages on basalt shorelines is the endemic thaidid, *Neothais harpa*, which feeds on shelled mollusks (see Fig. 6 C) and which may range sufficiently high on the shoreline to enable it to feed on littorines.

EULITTORAL ZONE

Six types of habitat are here included in the eulittoral zone, a zone roughly equivalent to the intertidal zone of other areas: the vertical faces of basalt cliffs and horizontal basalt platforms a meter or more above sea level; calcareous solution benches; tide pools; sandy beaches; fringing reefs; and shorelines with brackish-water incursions. Each has a characteristic assemblage of mollusks.

Basalt shorelines. — On basalt shorelines, whether cliff or sea-level platforms, 15 species of mollusks are consistently recorded. Among the most noticeable are the patellid limpets or opihi, *Cellana exarata* and *C. sandwicensis* (Fig. 6 A). The former occurs slightly higher on the shoreline than does the latter, but the two may intermingle on patches of shoreline which are partially encrusted with the calcareous alga, *Porolithon*. The shells of *C. sandwicensis* are often covered with algae, reflecting their lower habit. Interspersed among the opihi are the thaidids *Drupa ricina*, *D. morum*, *Morula granulata*, *Thais intermedia*, and *Purpura aperta*, and the opisthobranch, *Smaragdinella calyculata*. The minute bivalve, *Lasea hawaiensis*, is sometimes found in the holdfasts of the algae *Laurencia* and *Ahnfeltia* in this region. Where the seaward face of the basalt is honeycombed with lava bubbles and sea urchins, the snakehead cowry, *Cypraea caputserpentis*, the vermetid *Petaloconchus keenae*, the thaidid *Morula granulata*, and the bivalve *Isognomon incisum*, occupy some of the holes.

Tide pools. — Two types of tide pools occur in the windward Hawaiian Islands: marine pools on sea-level basalt outcrops (Fig. 2 C, D); and brackish water or lava ponds, termed anchialine pools (Holthuis, 1973) (Fig. 2 F).

The biota of marine pools varies with exposure. Those pools farthest from the sea and most extensively exposed are characterized by a sand substrate bound with blue-green algae, and the molluscan fauna is limited to specimens of the opisthobranch *Acteocina sandwichensis* and the gastropod *Eatoniella janetaylorae*. Seaward pools are densely turfed with a variety of algae such as *Padina*, *Jania*, and *Laurencia*. More than 50 species of mollusks have been recorded from these pools. In pools where there is at least a daily exchange of water, *Cypraea caputserpentis*, *Drupella ochrostoma*, *Peristernia chlorostoma*, and *Maculotriton bracteatus* are among the most commonly occurring species. Several opisthobranchs, such as the aplysiids *Dolabrifera dolabrifera*, *Dolabella scapula*, *Aplysia juliana*, and the colorful dorid, *Hexabranchus sanguineus*, are also frequent inhabitants of these pools. The dominant weed-dwelling micromollusks in the pools are *Tricolia variabilis*, *Barleeia calcarea*, and *Bittium parcum*, and the most frequently encountered rubble-associated mollusks are *Rissoina ambigua* and *R. miltozona*. Pools exposed to almost constant wave action are characterized by the sessile bivalve *Chama iostoma*, the vermetid *Serpulorbis variabilis*, the cones *Conus ebraeus* and *C. sponsalis*, and the cymatids *Cymatium nicobaricum* and *C. intermedius*.

Anchialine pools (Fig. 2 F) are found on the west coast of Maui and on the leeward coastline of Hawaii. Seaward anchialine pools harbor the endemic brackish-water mollusks *Theodoxus neglectus* and *T. cariosus;* shoreward pools where salinity may be less than 20 ‰ are characterized by a melanid.

Solution benches. — More than 35 species of mollusks have been recorded on solution benches on Oahu and Kauai, of which cones, miters, and the cowry, *Cypraea caputserpentis*, are the most conspicuous. Eight species of *Conus* are locally distributed across the benches, at densities of 0.5 per m^2 (Kohn, 1959a) (Fig. 4). *Conus abbreviatus* and *C. sponsalis* occupy a strip within 6 m of shore, the peak density of *C. ebraeus* occurs about halfway across the bench, and *C. chaldaeus* is found near the outer edge (Kohn, 1959a). *Mitra litterata* and *Morula granulata* have been recorded at densities of 0.05-0.22 per m^2 and 8 per m^2, respectively, on benches on Oahu (Kohn, 1970). The cones are primarily worm feeders, *Mitra litterata* feeds on sipunculids, *Morula* preys on other gastropods, and *Cypraea caputserpentis* is an herbivore. In addition, two suspension feeding mollusks are also abundant on these benches, the mytilid *Brachidontes crebristriatus* and the vermetid *Dendropoma gregaria*. *Brachidontes* forms conspicuous mats on the shoreward areas of the benches, *Dendropoma* forms crusts up to 5 cm thick over the substrate at the seaward edge. The micromollusks of benches are similar to those of marine tide pools, and include the weed-dwellers *Tricolia*, *Bittium parcum*, and *Barleeia*, and the rubble-associated *Rissoina ambigua* and *R. miltozona*.

Fringing reefs. — Reef assemblages are perhaps the most diverse of those occurring in inshore waters, reflecting a variety of habitats: solid substrates of calcareous algae and coelenterate corals; stands of frondose algae, such as *Sargassum* and *Acanthophora;* rubble; and sand patches. Among the larger mollusks, cones, miters,

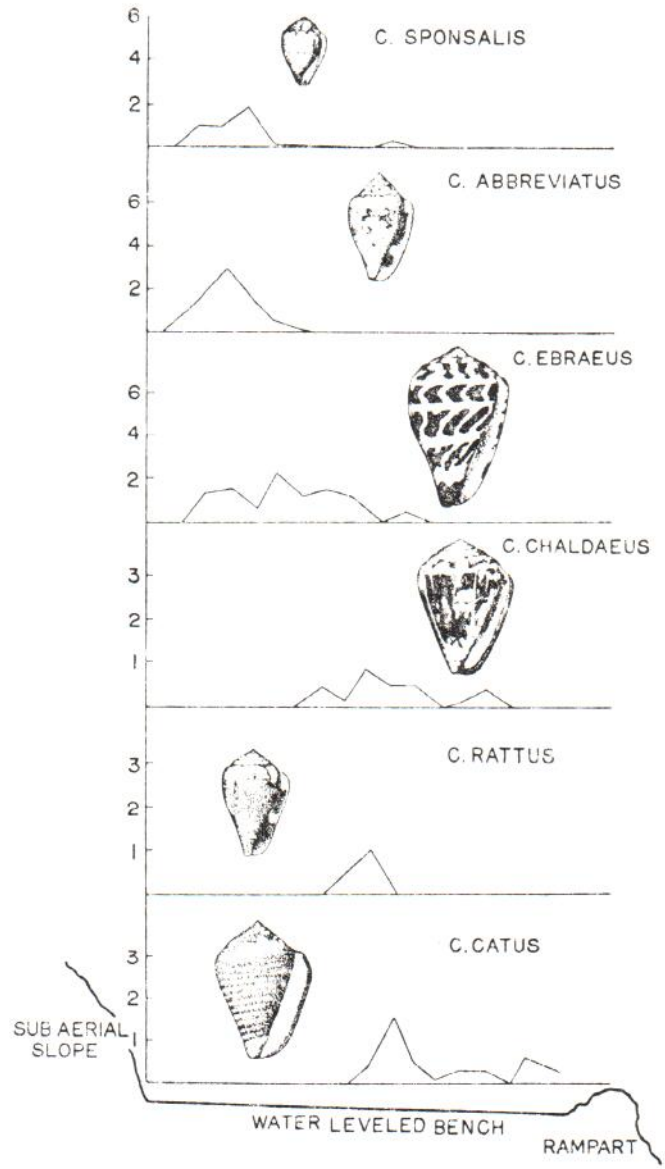


Figure 4.—The distribution of six species of *Conus* on the water-leveled bench at Milolii, Kauai, from the landward to the seaward edge. (From Hutchinson, 1965 after Kohn, 1959, by kind permission of Yale University Press.)

and cowries are common. The two most abundant cones on solid reef substrates on Oahu are *Conus flavidus* and *C. lividus* (Kohn, 1959a). The miters *Mitra litterata* and *M. assimilis* occur in depressions in the solid substrate and the cowries *Cypraea caputserpentis, C. helvola, C. isabella,* and *C. poraria* are found under loose rubble.

Distribution on reefs is patchy. Where there are colonies of zoanthid sea anemones, the architectonicid *Philippia variegata* may be common, and where the

halophyte *Halophyta hawaiiana* occurs, the minute nerite *Smaragdia bryanae* is often abundant. The most frequently occurring mollusks of sand patches on fringing reef flats are the sacoglossan opisthobranch *Plakobranchus ocellatus*, the cones *Conus pulicarius* and *C. pennaceus*, the tellinid *Tellina palatum*, and species of *Terebra* such as *T. gouldi*. The algal ridge is dominated by the vermetids *Dendropoma psarocephala* and *D. meroclista* and two species of *Hipponix*. The coral-associated mollusks *Coralliophila erosa*, *Drupella cornus* and *Rhizochilus madreporarum* occur on living coral at the outer edge of reefs. The cowries *Cypraea caputserpentis* and *C. maculifera* are also common.

Sandy beaches and sand flats. — Infaunal mollusks are not a dominant feature of the shallow water Hawaiian marine molluscan fauna, and relatively few infaunal mollusks are found on sandy beaches or in sand patches in the surge zone (Fig. 6 B). Four species of *Terebra*, *T. felina*, *T. penicillata*, *Hastula hectica*, and *H. inconstans* are high shore dwellers, found as high as wave action occurs on various beaches, their distribution associated with grain size and the distribution of their prey, cirratulid polychaetes (B. A. Miller, 1970). Intertidal sandflats in Kaneohe Bay, Oahu, and at Hanamaulu Bay, Kauai, harbor a more diverse fauna. In Kaneohe Bay, the infaunal biota includes species of *Terebra (T. affinis*, *T. crenulata*, *T. gouldi*, and *T. spaldingi)* (Miller and Coker, 1972), the bivalves *Ctena bella*, *Tellina palatam*, and *T. robusta*, the naticid *Natica gualteriana*, and the cephalaspid opisthobranch *Acteocina sandwichensis*. The introduced clam *Tapes japonica* is present in localized areas of the bay (see below). The tellinid *Macoma obliquilineata* is now almost solely confined to shallow, sandy patches in Hanamaulu Bay, Kauai, although it was at one time abundant in Kaneohe Bay.

Brackish-water assemblages. — Where streams and rivers enter the sea on Kauai, Oahu, and Maui, and where groundwater intrusions occur along the coastline of the leeward coast of Hawaii, four molluscan species are consistent indicators of salinities lower than those of sea water. The gastropods *Theodoxus neglectus*, *Planaxis labiosa*, and *Eatoniella janetaylorae* are found beneath rocks and rubble, and the bivalve *Isognomon californicum* encrusts the tide line of boulders in these areas.

SUBLITTORAL ZONE

Beyond the area of wave action and over the edge of the reef, at depths of 10 m off Anini, Kauai, and Waikiki, Oahu, but at lesser depths off the leeward coasts of Maui and Hawaii, there is, as Gosline and Brock (1960) describe it, "an almost altogether different world." Not only does the number of species of corals, mollusks, and fishes increase, but the composition of the fauna is quite different from that in shallow water (Fig. 5). Here, at depths of from 10 to 50 m are found the most spectacular of the Hawaiian marine mollusks: *Cypraea tessellata*, *C. tigris*, *C. sulcidentata*, *Mitra mitra*, *Nassarius papillosa*, *Latirus nodatus*, and such rarities as *Strombus vomer hawaiensis*, *Pterynotus elongatus*, and *Homolocantha anatomica*.

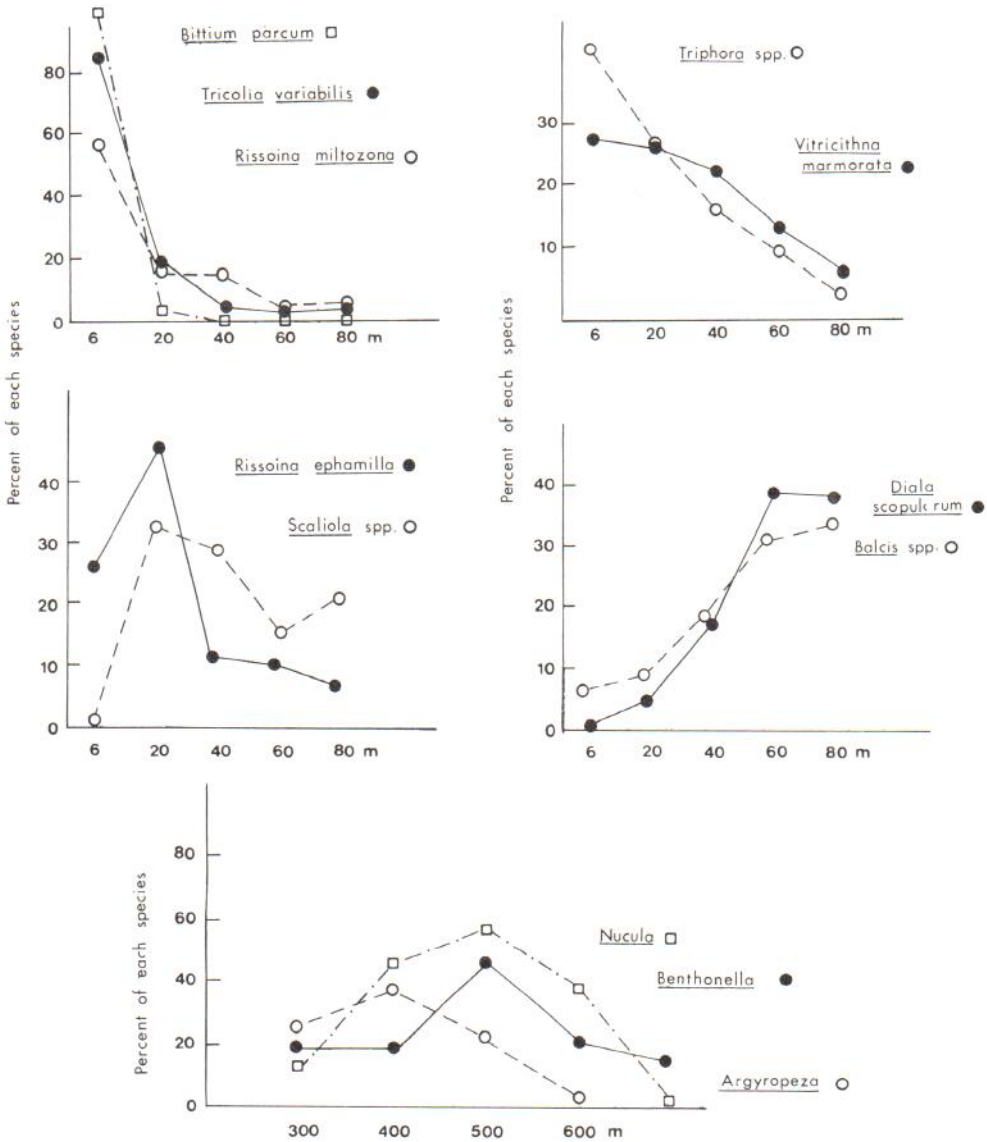


Figure 5.—Depth distribution of some commonly occurring micromollusks.

Assemblages in the subsurge zone are associated with substrate and depth, but there are, unfortunately, no quantitative studies of the distribution of larger mollusks. Estimates of frequency of occurrence determined from a series of dredge hauls at depths of from 20 to 300 m off the leeward coast of Oahu between Barbers Point and Diamond Head indicate that the most frequently occurring mollusks are *Drupella ochrostoma*, *Nassarius crematus*, and *Conus pulicarius*. Miters and terebrids were

found in 80 percent of the dredge hauls, with *Vexillum pacificum* and *Imbricaria olivaeformis* the most common miters and *Terebra affinis* and *T. thaanumi* the most common terebrids.

Quantitative studies of the distribution of micromollusks (those less than about 10 mm in greatest dimension) indicate that noticeable changes in species composition occur with depth. At depths greater than 20 m surge zone rissoids such as *Rissoina ambigua* and *R. miltozona* are replaced by *R. ephamilla* and *Vitricithna marmorata*, and the common shallow-water cerithids *Bittium parcum* and *B. zebrum* are replaced by the dialids *Diala varia* and *Cerithidium perparvulum*. The shells of these subtidal mollusks are smaller, more finely sculptured, and generally more delicate in appearance than are those of the surge zone.

Another molluscan assemblage, the dominant components of which include species of *Benthonella, Argyropeza*, cephalaspids such as *Ringicula* and *Scaphander*, and the bivalves *Bentharca* and *Nucula*, begins to appear at depths of about 200 m. This change in the fauna would appear to parallel the break which Struhsaker (1973) finds in the fish fauna at depths of 201 to 250 m (about 100 fathoms).

DISTRIBUTION WITHIN THE HAWAIIAN ISLANDS

Within an area comprising a chain of islands extending several hundred kilometers from north to south and which encompasses a variety of habitats, anomalies in distribution patterns are not unexpected. As early as 1871 William Harper Pease (1871d) noted that *Dolium melanostomum* appeared to be much more common in the leeward islands than in the windward islands. Pease's observations have since been confirmed, and other differences in presence/absence and dominance between the leeward islands and the windward islands have also been found.

Several presence/absence records can perhaps be explained in terms of habitat. Shorelines of the leeward islands of Kure, Midway, Pearl and Hermes Reef, Laysan, and French Frigate Shoals are entirely calcareous and less than a meter above sea level, providing different substrates and less intertidal habitat space than do the basalt shorelines of the windward islands. These facts may, at least in part, explain the observations that a single littorine, *Littorina pintado*, occurs on shorelines of the leeward islands, and that the northernmost record for *Nodilittorina picta* is on La Perouse Pinnacle, the basalt stack outside the reef at French Frigate Shoals. Opihi (patellid limpets) have a similar distribution; no opihi is known from the calcareous shorelines of the leeward islands, and the few specimens of *Cellana sandwicensis* recorded from French Frigate Shoals were found on La Perouse Pinnacle.

Another group of species, those associated with brackish water, are similarly absent in the leeward islands. *Theodoxus neglectus* and *Isognomum californicum* have not been recorded north of Kauai, but *Planaxis labiosa* is known from a few specimens at Laysan where there is a brackish water "lake." The curious occurrence of large numbers of *Eatoniella janetaylorae* from sediment samples at Pearl and Hermes Reef may indicate seepage from a freshwater lens on that atoll, although there are no hydrological studies to confirm this hypothesis.

Discontinuous distributions are not so easy to explain. *Neothais harpa* has not been recorded north of Kauai and *Thais intermedia* is recorded only from Laysan among the leeward islands. Living specimens of *Mitra multiplicata* and *M. edentula* are known from subtidal coral communities off the leeward coast of Hawaii but not from other islands in the Hawaiian chain. *Terebra gouldi* is known from Midway to Maui but is not recorded from Hawaii.

The dominance of one species on some islands and its rarity on others are equally puzzling. *Nerita plicata* is almost as common as *N. picea* at Midway and Pearl and Hermes Reef, but is known only from a few records from shorelines among the windward islands. The dominant thaidid on the reef flat at Midway is *Drupa grossularia*, a species recorded from only one or two specimens from depths of more than 10 meters off Oahu. At French Frigate Shoals the dominant predators of the reef flat are the thaidids *Morula porphyrostoma*, *M. uva*, and the fasciolarid *Latirus nodatus*. Of the three species, *M. uva* is common on windward island shorelines, *M. porphyrostoma* is frequently encountered on reefs but never abundant, and *L. nodatus* occurs subtidally at depths of 3 to 10 m in the windward islands. The small trochid *Euchelus corrugatus* is almost exclusively restricted to the leeward islands and Kauai. *Gibbula marmorea* is common in tide pools on Kauai, less frequently encountered on Oahu, and rare on Hawaii. The four species of the endemic pyramidellid genus *Nesiodostomia* are known only from localized occurrences on Kauai and Oahu, although specimens are abundant where they are found. The bed of the pearl oyster, *Pinctada margaritifera*, at Pearl and Hermes Reef which was exploited in the 1920's is the only record of such a bed in the Hawaiian Islands, although occasional oysters are seen subtidally in the windward islands.

FOSSIL HISTORY

Two deep drill holes through reef limestone and underlying clays into basalt at Midway establish a geologic section for the Hawaiian Islands that extends back through the Miocene, 20,000,000 years ago (Ladd and others, 1967). The Miocene coral fauna determined from these cores appears to be more diversified than are the modern assemblages (Ladd and others, 1967). Miocene fossils have also been dredged from a terrace found at depth of 500 m off Oahu; the terrace was at one time a shallow platform capped with coral reef but subsequently drowned, and the dredge hauls include six gastropods and twelve bivalves which appear to be forms associated with shallow water reef faunas (Menard and others, 1962).

Since the Miocene, subsidences and rises of coastlines caused by local tectonic movements and by rises and falls of sea level associated with the formation and dissolution of ice caps during the Pleistocene have occurred. Two cores from the Ewa plain which reached basalt at depths of 457 m and 243 m, respectively, suggest at least eight marine transgressions during the Pleistocene (Resig, 1969). At the base of the cores are fragments of the extinct endemic Hawaiian oyster, *Pycnodonta kamehameha*, which is also common in the oldest known fossil reefs above sea level, those of the 28 m Kaena stand of the sea. In the fossil assemblages of the more recent Waimanalo stand are two other endemic, extinct mollusks, *Strombus mutabilis ostergaardi* and *Septifer vaughani*, and several marine molluscan species well known

elsewhere in the Pacific today but which do not now live in Hawaiian waters. Among these are *Lambis chiragra* and *L. truncata*, and several species which are found in Hawaii today, including *Turbo sandwichensis* and *Arca ventricosa*. The presence of the oyster, *Lambis*, and the proportionately large numbers of *Turbo* and *Arca* in the assemblages are indicative of a quite different type of reef habitat than that now occurring in Hawaiian waters.

Sections of the Waimanalo stand, which have been dated as occurring some 100,000 years ago, also are marked by the presence of another extinct, endemic oyster, *Ostrea retusa*. This oyster and its associated fauna, which includes an extinct brackish-water nerite, are also indicative of a different biota than is found in Hawaiian waters today.

The data at present are too sparse and unstudied to draw conclusions on the course of the history of the marine mollusks of the Hawaiian Islands, but they indicate that several changes in the biota have occurred during the period of time that the islands have been above sea level. The presence of endemic species in the earliest Pleistocene deposits suggests that speciation had occurred prior to the Pleistocene, an observation consonant with Briggs's (1966) suggestion that the high proportion of endemism in the marine fauna of the Hawaiian Islands is to be associated, not with shifts in temperature during the glaciation of the Pleistocene, but with an earlier change in temperature which occurred in the Pacific in the Miocene.

COMPOSITION AND DERIVATION OF THE HAWAIIAN MARINE MOLLUSCAN FAUNA

The marine molluscan fauna of the Hawaiian Islands is estimated as consisting of about 1,000 species. The Gastropoda account for about 80 percent of the species, the Bivalvia about 16 percent, and the Cephalopoda, Amphineura, and Scaphopoda 4 percent of the mollusks.

Perhaps the most conspicuous feature of the Hawaiian marine molluscan fauna, compared with the vast and spectacular fauna of the Indo-Malaysian Archipelago and such island groups as Fiji and the Marianas, is its attenuate character. Attenuation is not of the sort characteristic of insular terrestrial biotas, however, for there are no strikingly disharmonic gaps at either the ordinal or familial levels, although among the Cephalopoda there are no members of the Sepiidae, and in the Bivalvia the giant reef-dwelling Tridacnidae are absent. Among the families of gastropods that occur within the Pacific Basin, none of those that are absent in the Hawaiian Islands, such as the Haliotidae, Acmaeidae, and Volutidae, contribute significantly in species numbers to insular faunas of the central Pacific. Attenuation appears to occur primarily at the generic and specific levels; of the Micronesian reef gastropods listed by Demond (1957) 22 percent of the genera are absent in the Hawaiian Islands. Cones, cowries, and miters show a similar attenuation: 60 species of cones are recorded from Fiji (Cernohorsky, 1964b) but 40 are known in Hawaii; 60 cowries occur in Fiji (Cernohorsky, 1964a), 58 in the Ryukyu Islands (Cate, 1967) but 30 are found in Hawaii; 135 miters are found in Fiji (Cernohorsky, 1965), 100 in Hawaii.

The Hawaiian molluscan fauna exhibits a higher proportion of gastropod species and a correspondingly lower proportion of bivalves than apparently occurs in tropical continental areas. The gastropod: bivalve species ratio in the Philippines, for example, is 67:33 (Kay, 1967a). A high gastropod: low bivalve proportion comparable with that in the Hawaiian Islands occurs in other insular areas such as the Ellice Islands (Hedley, 1899), the Kermadecs (Iredale, 1910), Cocos-Keeling Islands (Maes, 1967), and Line Islands (Kay, 1971). These differences may perhaps be explained in terms of the peculiarities of an insular environment. Gastropods are, for the most part, epifaunal, living upon and/or associated with rocks, stones, shells, and algae; bivalves are typically infaunal, inhabiting the sandy or muddy surface of the sea bottom. Island coastlines lack expanses of nutrient-rich, silty sand ocean bottom characteristic of continents and ancient archipelagoes, and thus the niches for infaunal bivalves. In this connection, it can be noted that those bivalves which contribute most conspicuously to the species composition of Hawaiian waters are predominantly epifaunal.

Endemism. — Biogeographers have long recognized that insular biotas exhibit a higher proportion of endemics than do continental faunas. Ekman (1953) finds "the high proportion of endemicity among marine organisms in the Hawaiian Islands" unusual in his analysis of marine zoogeography.[1] Briggs (1974) attributes the relatively high degree of endemism among marine organisms in Hawaiian waters to "a long, stable climatic history and a considerable geographic isolation."

The Hawaiian subspecies of at least four polytypic molluscan species may represent "relict" species, that is, species representing isolated genetic pools which survived a once widespread Pliocene or Pleistocene range. *Strombus vomer hawaiensis* is a closer relative of *S. v. vomer* of the Western Pacific arc (also represented in Pliocene fossil deposits in Taiwan) than it is to the oldest form in the group, *S. v. iredalei*, found in the Dampierian province from Western Australia to the Gulf of Carpentaria (Abbott, 1960). *Turris crispa intricata* is the Hawaiian subspecies of a species represented by the widespread *T. c. crispa* which ranges from Madagascar to the New Hebrides and the Loyalty Islands, *T. c. variegata* from the west coast of India, and *T. c. yeddoensis* from Japan (Powell, 1964). The pecten, *Pecten ?benedictus diomedeus*, may be representative of a race of a polytypic species which has a Recent range from the Mediterranean through the Indian and Pacific oceans (Fleming, 1962).

With perhaps two or three exceptions among the marine mollusks (the pyramidellid genus *Nesiodostomia* and some of the bivalve genera described by Dall, Bartsch, and Rehder (1938)), endemicity does not occur at higher taxonomic levels than those of the species and subspecies. I estimate an endemicity of about 20 percent at the specific and subspecific level. The over-all figure is not in itself especially useful, however, because endemicity varies among groups of mollusks. Those mollusks with long-lived pelagic larvae, such as the Cymatiidae and Tonnidae, show little regional

1. It is worth noting that the term "high proportion" does not mean the same thing to the terrestrial biogeographer as it means to the marine worker: the native terrestrial biota of the Hawaiian Islands exhibits an endemicity of 95 percent (Zimmerman, 1948) whereas an endemicity of 30 to 45 percent is considered high for marine faunas (Briggs, 1966).

differentiation, and many of the opisthobranchs are circumtropical in distribution. Among other mollusks that live subtidally it is difficult to find a pattern: 20 percent of the Cypraeidae and 60 percent of the Turrinae are presumably endemic. On the other hand, those forms which live highest along the shorelines and those which are associated with brackish water appear to have consistently high percentages of endemicity. In the spray zone all four species of Patellidae, and one of four species of Littorinidae are endemic. In the brackish-water assemblage, three of four species are endemic. It is perhaps significant in this connection that the one species of *Conus* which may be endemic (*Conus abbreviatus* Reeve, 1843) occurs in the intertidal, and that the three species of the Thaididae which are endemic are found in the intertidal.

Endemicity may be associated with both ecological and physiological factors. It is well known that animals on the periphery of their ranges often exhibit larger sizes than they do toward the center of their distribution. The Hawaiian cowries, among others, exhibit the phenomenon: the mean length of *Cypraea tigris* in the Hawaiian Islands is 117 mm; in other areas of the Pacific it is 77 mm (Kay, 1961a; 1961b). Additionally, many of the prosobranchs which are widely distributed in the Indo-West Pacific live in deeper water in the Hawaiian Islands than they do elsewhere: *Cypraea tigris*, *C. schilderorum*, *Latirus nodatus*, *Distorsio anus*, and *Bursa bufonia* are familiar shallow-water species elsewhere in the Pacific and Indian oceans but in the Hawaiian Islands these species occur at depths of more than 3 m.

Many Hawaiian plants and terrestrial invertebrates are restricted to particular islands in the Hawaiian chain. Insular differentiation among marine organisms is less well documented, but there are several examples of differences in color pattern and size among marine mollusks which suggest isolation of gene pools. On Kauai shells of the trochid *Gibbula marmorea* are predominantly green; on Hawaii they are red. Specimens of *Peristernia chlorostoma* from Laysan are the only ones in the Hawaiian Island chain which exhibit a brilliant yellow aperture characteristic of the species elsewhere in the Pacific. Shells of *Cypraea isabella* are sometimes tipped with orange in the leeward islands as they are elsewhere in the Pacific, but among the windward islands the shells are tipped with brown. The shells of *Casmaria erinaceus kalosmodix* from Midway to Necker are of unusually large size, reaching lengths of 103 mm but they are progressively smaller among the windward islands (Abbott, 1968). Shells of *Cypraea tigris* on Midway are larger than they are in the windward islands (Kay, 1967a).

Relationships. — The Indo-West Pacific relationships of the Hawaiian marine mollusks have been recognized since at least the end of the 19th century when Cooke (1895) wrote of the great oceanic gap between the Hawaiian Islands and the Americas. But from which areas in the Pacific have the Hawaiian marine mollusks derived? If well-studied groups such as *Cypraea*, *Strombus*, *Pinna*, and the Turrinae are divided into three elements — those species that range through the Indo-West Pacific, those that are restricted in their distribution to the Pacific basin, and an endemic element — a suggestive pattern emerges. The proportion of Indo-West Pacific species falls and the proportion of Pacific species rises the farther east the island group, except in the Hawaiian Islands. Here, the proportion of Pacific species is lower than it is for islands at the same longitude, for example, the Line Islands, and, in addition, an endemic element is present.

Endemic Hawaiian marine mollusks appear to be more closely related to the Indo-West Pacific faunal element than they are to the Pacific species group. In *Strombus, S. helli* is apparently an offshoot of *S. haemastoma* which occurs in the Marshall Islands but not in the Line Islands; *S. vomer hawaiensis* is related to *S. vomer vomer* from Okinawa, and *S. mutabilis ostergaardi* to *S. mutabilis* which occurs to the west but not to the south in the Line Islands (Abbott, 1960). Among the Turrinae, the Hawaiian subspecies of *Turris crispa* and three species of *Xenoturris* have their nearest relatives either in the Marshall Islands or in Okinawa (Powell, 1964). On the other hand, there are several miters which are known only from Polynesia and Hawaii.

The occurrence of a proportionately large number of species related to forms to the west rather than the south is in agreement with present interpretations of the geologic history of the Pacific basin. The first island elements in the north Pacific are thought to be the now submerged seamounts forming the Mid-Pacific mountains which lie between Hawaii and the Marshall Islands. Many of the seamounts which make up the Mid-Pacific mountains are now guyots, but during Cretaceous times and possibly into the Tertiary they projected above the sea (Rehder and Ladd, 1973). These seamounts conceivably served as the stepping-stones by means of which the Hawaiian fauna derived from the rich Indo-West Pacific fauna to the west.

ECONOMIC ASPECTS OF THE MARINE MOLLUSKS

The Hawaiian Islands were inhabited at least as long ago as A.D. 400, settled by migrant Polynesians who came from the Marquesas and Tahiti (Kirch, 1974). Pacific island people have a long tradition of utilizing marine mollusks for food, tools, and ornaments. That tradition was continued in Hawaii by the Polynesian settlers and remains today, albeit that marine mollusks play a less significant role in the economy of the islands than they did 200 years ago, and that the indigenous marine mollusks have been augmented by the introduction of several species for commercial production.

NATIVE HAWAIIAN USE OF MARINE MOLLUSKS

The variety and numbers of gastropod and bivalve shells found in archaeological sites on all the windward Hawaiian Islands indicate that mollusks were a significant source of food, tools, and ornaments in native Hawaiian culture. Among the most commonly encountered gastropods, which were presumably cleaned of their soft parts for food with bone picks or other means, are those of the opihi *(Cellana* spp.), nerites, cowries, thaidids (*Morula* and *Drupa*), and cones. Opihi shells are especially widespread, found in the earliest dated middens at South Point, Hawaii (Emory and Sinoto, 1969) and Bellows Field (Pearson and others, 1971). A sharp-edged stone was used to knock opihi from the rocks, and opihi fishing was called *ku'i 'opihi* (opihi pounding). Bivalve shells are less common in middens than are those of gastropods. Bivalves in general were called *ōlepe*, and may have been cooked over driftwood fires or in calabashes of hot water (Bryan, 1915). Both octopus and squid were also fished. The

two common littoral octopods, *he'e mali*, the day squid *(Octopus cyanea)*, and *he'e pūloa*, the night squid *(O. marmoratus)*, were caught with a cowry shell lure, as described in an ancient pule or poem, "here is the cowry — a red cowry to attract the squid to his death" (in Bryan, 1915).

The shells or parts of shells of many gastropods were utilized as tools: opihi shells and the backs of large cowries (*Cypraea maculifera* and *C. mauritiana*) as scrapers for breadfruit and taro; terebrids as stoppers for gourds; the columella of miters and fasciolarids for drills; pearl shell for fishhooks on Oahu and Kauai (Sinoto, 1967) and lures (Malo, 1951). Giant triton shells *(Charonia tritonis)* were employed as trumpets (called "pu"). Shells were also used as ornaments, strung as leis for neckwear, anklets, and bracelets, or hung as pendants. Among the artifacts of the Cook voyages are leis of the shells of *Nerita polita* and the tops of cone shells (see Force and Force, 1968). Small columbellid shells were strung by the people of Niihau into long ropes, a custom practiced today.

WESTERN USE OF MARINE MOLLUSKS

With the advent of Western culture, marine mollusks continued to be utilized for food in Hawaii. Among the mollusks listed in the fishmarkets on Oahu about 1900 and as late as 1927 (Cobb, 1903; Henderson, 1927) were *leho* (cowries), opihi (*Cellana* spp.), conch (*Neothais harpa* and *Purpura aperta*), *wī (Neritina granosa)*, *he'e* (octopus), and *mūhe'e* (squid). In 1901, 75,500 pounds, or 2 percent of the "catch" in the fishmarkets, was composed of mollusks. But habits and customs change, as has the availability of marine mollusks along the shorelines. In 1949, campfire sites along the leeward shoreline of Kauai abounded with the broken shells of *Cypraea mauritiana*, *C. maculifera*, *Charonia tritonis*, and *Tonna perdix*, the soft parts of which had been roasted for consumption (Kay, 1949). The same campfire sites today are marked only by the shells of opihi and the small bivalve *Isognomon perna*. Between 1964 and 1975, opihi in Honolulu fishmarkets averaged about 14,000 pounds annually, a drastic reduction from the 75,000 pounds recorded for the beginning of the century.

A pearl oyster (probably *Pinctada nebulosa*) was perhaps the first Hawaiian marine mollusk to have come to the attention of Western visitors. The great bay west of Honolulu, known today as Pearl Harbor, had early come to be called "Wai Momi," or "Pearl Water." In 1788, John Meares became intrigued with the idea of a possible pearl fishery, and King Kamehameha apparently soon "learned of their value, kept the fishing to himself, and . . . [employed] . . . divers for that purpose" (Campbell, 1822). In 1817 it was noted, "There are many divers employed here, diving for the pearl oysters, which are found in great plenty. We saved them much trouble and labor by presenting the King with an oyster dredge we had on board with which Tameameha was highly delighted" (Corney, 1896).

Opinions on the quality of the Hawaiian pearls were mixed. Broughton (1804) states they were "of good quality"; Kotzebue (1821) says the pearls he received were "very beautiful"; Choris (1822) mentions "trés belles perles." On the other hand, Macrae (1922) writes "they are poor and ill-formed"; Mathison (1825) states they were of inferior quality; and Menzies (1920) says they were "in general small and very indifferent." There are no records of the numbers of pearls or their worth during

those early years, except for those of Francisco de Paula Marin, an early 19th-century resident. Marin's diary records transactions for at least 61 pearls during a period of four months in 1812: four pearls bought for one pair of scissors, two for a knife, one for $4.00, and so on (Marin, 1973).

Pearls again came into prominence in 1927 when a bed of pearl oysters *(Pinctada margaritifera)* was discovered at Pearl and Hermes Reef. Several tons of shells were brought to Honolulu in 1928 and sold for the manufacture of pearl buttons and the pearls which the oysters contained. Several pearls were sold for prices as high as $1,500 and $2,000 (Galtsoff, 1933). Because of the danger of overfishing, the Territorial Government and the United States Bureau of Fisheries undertook a study to outline methods for the conservation and development of the pearl oyster beds. A survey of the lagoon indicated, however, that pearl oysters were already scarce, restricted to a relatively small area of Pearl and Hermes Reef. Regulations were established which remain in effect: "It is unlawful for any person, firm, or corporation to take, molest, collect or destroy any kind of pearl oyster found in any of the waters under the jurisdiction of the Territory [now State] of Hawaii. . . ." Despite these precautions, surveys of the former pearl oyster beds in 1950 and 1969 indicate no more than one or two living pearl oysters.

INTRODUCTIONS

Although the terrestrial biota of the Hawaiian Islands has been drastically changed by the purposeful and accidental introduction of both animals and plants, relatively few marine organisms have been introduced in Hawaiian waters, and still fewer have become established.

Perhaps the first introduction of a marine species was that of the eastern oyster by Captain John Paty who imported a barrel of seed oysters for implantation in Pearl Harbor in 1866 (*Honolulu Advertiser,* 1895). Other attempts followed: in 1877 James Campbell attempted an oyster planting experiment at Honouliuli, Oahu (*Honolulu Advertiser,* 1947); in 1883 Allen Herbert had 300 oysters from San Francisco planted in Kaneohe Bay (Cobb, 1902); and in 1890 S. M. Damon introduced seed from San Francisco at Moanalua, Oahu (McClellan, 1938). The most successful of these introductions was that of John Colbourn in 1893 and 1895, as indicated by an advertisement in a contemporary newspaper: "Eastern transplanted oysters from John F. Colbourn's pond at Pearl Harbor . . . are of much finer flavor than oysters imported on ice" (*Independent,* May, 1895). Few, if any, of these early attempts were successful, and in the 1920's the Division of Fish and Game of the Territorial Government's Board of Agriculture and Forestry began systematic transplants, introducing eastern oysters to Kaneohe Bay and Pearl Harbor, Oahu (Coleman, 1923). In 1939 two and one half tons were dug from Kaneohe Bay and distributed to new localities (Brock, 1960). Recent surveys (Sparks, 1962; Brick, 1970; Kawamoto and Sakuda, 1973) indicate that two species *(Crassostrea gigas* and *C. virginica)* grow in potentially utilizable beds in the West Loch of Pearl Harbor and in Kaneohe Bay, Oahu, and oysters have been commercially harvested from fishponds on Molokai.

Another early introduction, that of *Tapes japonica,* may have been made at the beginning of the century by Japanese immigrants. The initial stocks were supplemented

by a consignment of ten barrels transplanted in Kalihi, Pearl Harbor, and Kaneohe Bay, Oahu, in 1920 (Edmondson and Wilson, 1940). The bivalves, known locally as the "Damon clam," grew and reproduced so successfully that 400,000 pounds were shipped to Kauai, Hawaii, Lanai, and Maui in 1957 (Brock, 1960). Harvestable beds developed only in Kaneohe Bay, however, and between 1965 and 1969 the beds were opened to public fishing for a month each year. In 1965 10,000 clam diggers harvested the beds, and in 1968, 41,000 clam diggers were recorded. Overfishing and, perhaps, changes in water quality associated with pollution from land runoff and sewer outfalls in Kaneohe Bay reduced the stocks, and the clam beds have been closed since 1969.

Of other marine mollusks purposefully introduced into Hawaiian waters, *Trochus niloticus* and *Mercenaria mercenaria* have apparently settled and are reproducing.

HISTORICAL RESUMÉ

THE ENGLISH VOYAGES OF EXPLORATION: 1778-1850

It is appropriate that the first Western records of Hawaiian mollusks should be traced back to Captain James Cook's visit to the Hawaiian Islands in 1778. These records were not the result of the official scientific investigations undertaken during the third voyage, however, but rather of the desire of amateur collectors in England to enhance their natural history cabinets with specimens from the newly discovered lands in the "South Seas." In an official version of the Cook voyage the mollusks of the Hawaiian Islands were written off: "The few shell fish seen by us were chiefly converted into ornaments, though they were destitute of the recommendation of either beauty or ornament" (Cook and King, 1784). Several of those disappointing "shell fish" reached England unofficially in the hands of members of the ships' company and two, *Hydatina physis* and *Nerita polita,* were the subjects of folio-sized, hand-colored plates in Thomas Martyn's famous *Universal Conchologist* (1784-1787).

Of other shells which must have arrived at the same time we have no direct records. Broderip and Sowerby (1829), describing *Bulla* [*Smaragdinella*] *calyculata* from Pitcairn Island, noted that specimens from the Hawaiian Islands had been brought by Captain Cook in the *Endeavour,* and that the shells were pierced, "having been strung by natives." Because the *Endeavour* sailed only on Cook's second voyage, the authenticity of the Broderip and Sowerby locale may be questioned, but it is also possible that they erred in attributing the Hawaiian specimens to the second voyage, for the shells are common in the Hawaiian Islands. Sowerby (1844) also attributed *Columbella* [=*Euplica*] *varians* to the Hawaiian Islands via the *Endeavour;* this species also occurs in the Islands and the record may similarly be authentic.

The second voyage to visit Hawaii, that of Captains George Dixon and Nathaniel Portlock in the *King George* and *Queen Charlotte* (1785-1788), left more complete records of the natural history of the islands. To Dixon (1789) goes the credit for describing the first of the now famous Hawaiian land shells, *Helix apex fulva* [*Achatinella apexfulva*]. The specimens from which the species was described were in a shell lei presented to members of the ships' company and the types have a pierced apex. Pilsbry and Cooke (1914) pinpoint the locality of Dixon's specimens as Opaeula Gulch, Oahu, and suggest that subsequent descriptions of the same species under

different names by Chemnitz (1795 as *Turbo lugubris*) and Lamarck (1822 as *Monodonta seminigra*) were based on shells from Dixon's lei.

Of marine shells Dixon wrote: "At the same islands are great plenty of beautiful shells such as *Cypraea tigrina* [*Cypraea tigris*], *C. mauritiana, C. talpa,* and others of that genus . . . and numberless species of the smaller kinds, of which last the natives form necklaces, bracelets, and other ornaments" (Dixon, 1789).

There is no record of the shells which may have been collected by Captain George Vancouver (1792-1794) and his company, despite the fact that the ships' complement included a professional naturalist, the botanist Archibald Menzies. Vancouver's voyage was not without molluscan interest, however, for Vancouver himself wrote: "The pearls I saw were but few, and consisted of three sorts, the white, yellow, and lead colour" (Vancouver, 1798).

There are also a number of references which indicate that amateur collectors in England acquired shells from the Hawaiian Islands from a variety of sources subsequent to the Cook voyage. The catalog of the collection of the Reverend C. M. Cracherode, compiled between 1791 and 1799, includes a description of "The broad faced netted cowry. 2 specimens, one uncoated from the Sandwich Islands" (Gray MS., British Museum (N.H.)). Specimens of the nerite figured by Thomas Martyn were listed in the *Museum Calonnianum* (Humphrey, 1797), in a catalog of the Bullock Museum (Barde, 1814), and in the collection of Sir Ashton Lever (1806). The Leverian collection also included "a curious necklace of cowry shells," "the black mother-of-pearl shell," and "the black margaritifera, with the border complete" (Lever, 1806). In the *Index Testaceologicus* (Wood, 1818) two species are erroneously recorded, *Trochus byronianus* and *Venus stutchburyi;* but in the third edition (Wood, 1828), two species are correctly assigned to Hawaii, *Turbo* [*Littorina*] *pintado* and *Nerita* [*Theodoxus*] *cariosus*. The specimens of the latter two species were in the collection of J. E. Gray who became Keeper of Zoology at the British Museum (Natural History).

Two cowries and a nerite were described during this period from unknown locales; all three are now known to be endemic to the Hawaiian Islands, and the specimens must be presumed to have arrived in England on some of the early voyages. *Cypraea tessellata* was described by Swainson (1822) from a specimen in the collection of Mrs. Mawe, an ardent collector of natural curiosities. There are also records of two other specimens of the same species, one in the collection of Dr. Joseph Goodall, Provost of Eton (J. E. Gray, 1825), and another in that of Mrs. Bligh, wife of the famous vice-admiral (Swainson, 1822). *Cypraea sulcidentata* was described by J. E. Gray (1824) from specimens in his own collection and in that of the Earl of Tankerville. And from the Tankerville collection Sowerby (1825) described *Neritina granosa,* noting that it came "from a fresh-water stream in one of the South Sea Islands." The types of the granulated nerite which are now in the British Museum (Natural History) have pierced apices, a feature noted by Sowerby who "supposed that they have served as ornaments."

By far the richest collection of Hawaiian mollusks to reach England after Cook's visit was that made by Captain Lord Byron and the naturalists of his company on the

Blonde, the botanists Andrew Bloxam and James Macrae in 1826. Bloxam (1925) gives a lengthy account of the mollusks:

> Of shell fish the pearl oyster is the most valuable, and the pearls generally good. We found besides, the *Bulla amplustre* [*Hydatina amplustra*], *Buccinum* [*Terebra*] *maculatum*, *Volutae* [*Mitra*] *papalis* and *episcopalis*, *Conus ebraeus*, *Cypraea arabica* [*Cypraea maculifera*], *C. carneola*, *C. guttata* [*?C. vitellus*], *C. mauritiana*, and *C. isabella;* and also several varieties of *Murex*, *Nerita* [*Theodoxus neglectus* Pease], *Patella* [*Cellana*] and *Turbo*.

To this list J. E. Gray (1825) added *Cypraea australis* [*Trivia insecta*].

Bloxam's diary reflects the difficulties early visitors encountered in finding marine shells, which were apparently no more plentiful along Hawaiian shores in 1825 than they are today:

> Shells are not numerous here, cowries and nerites are most abundant, though all have holes bored in them. . . . I saw several beautiful cowry shells but the natives always break them to procure the fish which they feed upon. . . ." (Bloxam, 1925).

Of a stroll around Diamond Head Bloxam wrote "I procured a quantity of small shells of a common sort," and "I walked along the shore towards the bay of Whytee [Waikiki] to see if I could procure any shells, but I found none worth picking up." On the island of Hawaii he "proceeded along the coast eastward . . . scarcely any shells to be found" (Bloxam, 1925).

Byron's voyage provided William Swainson with several species of land shells for which Swainson erected the genus *Achatinella* (Swainson, 1828). The source of Swainson's shells is indicated in a letter from Bloxam to Swainson, written from Valparaiso, Chile, on September 18, 1825, during the return voyage to England:

> I regret to say that I was very unsuccessful in procuring shells at the Sandwich Islands, not having a single mitre and but few cones which are well known as the *C. ebroeus*. I have procured however a good selection of the beautiful little land-shells, amounting to about ten varieties, some with reversed mouths, they apparently belong to the volutes of Mawe's Linnaean System. . . . my Brother I hope will give you duplicates of most of the Sandwich Island . . . land-shells (Rothschild, 1893-1900).

Other English voyages prior to 1850 produced little in the way of relevant molluscan records. From the voyage of Captain Beechey and Lieutenant Belcher in the *Blossom*, *Patella argentata* [*Cellana talcosa*] is recorded which was then attributed to Chile, but which is now known to be endemic to the Hawaiian Islands (Gray and Sowerby, 1839). Belcher returned to the Hawaiian Islands in command of the *Sulphur* in 1837, accompanied by the surgeon Richard Brinsley Hinds, who subsequently published a monograph on the genus *Terebra*, among other things. In Hinds's (1844) monograph only one species, *Terebra inconstans*, is referable to the Hawaiian Islands, but the specimens from which the species was described had been previously collected and were in the British Museum (Natural History) when Hinds assembled his material. There are, however, specimens of *Smaragdinella calyculata*, *Nerita*, *Conus*, and *Tellina* now in the British Museum (Natural History) which were collected in the islands by Belcher and Hinds.

Hinds's observations on Hawaiian mollusks are recorded in his journal on the two occasions that the *Sulphur* visited the Islands during the three-year voyage. Of the visit in 1839, he wrote:

> The explorings of the botanist soon bring him into acquaintance with the land shells, which here are numerous though always small. On the mountain sides, and in the streams of the vallies [*sic*] ten species were collected. Those from the hills were usually found in the moist soil under the vegetation. Three different species were heterostrophic shells, and there is a remarkable similarity in the characters of the different kinds. The freshwater shells were a Physa and 2 Neritina. Of the sea shells I can say little or nothing. From all I could learn there is some variety; and a little difference in the productions of different islands. All I saw really native were Bulla, Conus, Pleurotoma, Patella . . . (Hinds, 1968).

In 1839 Hinds wrote in a similar vein:

> To land shells I devoted but a few hours, and yet became acquainted with 21 species; of nearly the whole of which we have specimens. They are as follows: Helix 2 sp., Achatina byronii, Bulinus otaheitanus and other species. Pupa –, Neritina 2, perhaps 3 species, Physa, Lymnaea. I heard of no freshwater bivalve. It is singular that three species of these land shells, are both dextral and sinistral, and there are perhaps more; the sinistral individuals are extremely numerous and are of equal interest, and the variety of markings is great, to some extent different vallies [*sic*] have peculiarities. These shells are well worth studying.
>
> The sea shells are numerous and pretty; the following came before our notice, Cassis cornutum, Buccinum perdix, Bulla amplustris, Cypraea – sp. and var. Venus 2 sp. Venerupis? 1 sp., Cerithium, Neritina – 2 sp. Natica, Conus figulinus, Columbella 2 sp., Murex 2 sp., Strombus, Turbo, Purpura, Helix 3 sp., Achatina Byronii, Bulimus, B. taheitensis, Physa, Pupa, Perna'' (Hinds MS, British Museum (N.H.)).

The voyage of Captain Kellett and Lieutenant Wood in the *Pandora* in 1850 is described by Carpenter (1857) as one of ''the many wasted opportunities of obtaining valuable information.'' Forbes (1852), who described the mollusks collected during the voyage, notes that the locality data for many of the specimens had become mixed, and the three marine gastropods he attributes to the Hawaiian Islands *(Nassa cooperi, N. woodwardi, Purpura fuscata)* are now known to be species occurring on the west coast of the United States. A number of species of *Achatinella* were correctly attributed to the Hawaiian Islands, however.

FRENCH AND RUSSIAN RECORDS: 1785-1850

The French sponsored eight voyages, all ostensibly for scientific and/or commercial purposes, which touched the Hawaiian Islands prior to 1850. The first French voyage, 1817-1820, to report on the natural history of the islands was that of the *Uranie* under the command of Louis de Freycinet. The botanists Gaudichaud and Agardh published extensively on Hawaiian plants, but the medico-naturalists Quoy and Gaimard, who described the mollusks of the voyage, record only *Aplysia* [*Stylocheilus*] *longicauda* and a ''nerite marine'' (Quoy and Gaimard, 1832). The voyage of Eydoux and Souleyet in 1841-1852 on the *Bonite* was more profitable and 16 Hawaiian mollusks were described. The collection was sent by order of the executors of the estate of Souleyet to the British Museum (Natural History) where the types are now held (see J. E. Gray, 1855).

There are several references in French conchological works indicating that a number of shells from the Hawaiian Islands were in collections on the European continent during the early years of the 19th century. Bruguière's (1792) reference to *Conus cancellatus*, although quoted by Dillwyn (1817), was apparently an error (Kohn, 1959b). In the second edition of Lamarck's *Animaux sans vertebres* . . . *Terebra maculata* "from the Islands where Captain Cook was killed" (Deshayes, 1822 trans.), *Neritina sandwichensis* and *N. granosa* (Deshayes, 1838), and *Monoceros unicarinatum* (Deshayes, 1844) are mentioned. Later publications by Deshayes (1859), on *Terebra* and *Vanikoro*, and Recluz (1841), on *Nerita*, were based on their studies of the Cuming collection in England.

Accompanying the Russian voyages which reached the Islands in the early years of the 19th century were two naturalists whose names are closely associated with the Hawaiian flora and fauna, Adelbert Chamisso and Frederick Escholtz. Both sailed with Kotzebue, Chamisso arriving on the *Rurik* in 1815, and Escholtz on the *Predpriatie* in 1823 and again in 1826. Chamisso (1829a) described a single molluscan species, *Auricula o-waihiensis*, and recorded a juvenile specimen of *Auricula sinistrorsa*.

MISSIONARIES, TRAVELERS, AND THE U. S. EXPLORING EXPEDITION

The Hawaiian Islands during the early years of the 19th century served not only as ports of call for the great voyages of exploration, but they were also links in the system of trade in furs, sandalwood, and whale oil which extended across the Pacific, and the destination of both missionaries and travelers. Neither fur trader nor whaler contributed much to the growing knowledge of Hawaiian natural history, although John Meares looked into the possibility of exploiting the pearls mentioned by Vancouver, Bloxam, and Kotzebue (Meares, 1790), and the presumed activities of the wood-boring bivalve, *Teredo*, were recorded briefly by Frederick D. Bennett (1840), who commanded the whaling ship *Tuscan*.

Among the first missionaries to collect Hawaiian mollusks was the Reverend C. S. Stewart, who, after a residence of three years in the Islands, 1823-1825, returned to the east coast of the United States and presented specimens of *Achatinella* to the American conchologist Jacob C. Green. The two species described by Green (1827) represent the first mention of Hawaiian shells in the United States. Other missionaries followed Stewart's example, and John C. Jay noted several species "received from missionaries in the Sandwich Islands" in his *Catalogue* (Jay, 1839). One of the most perceptive missionaries during those early years was the Reverend Edward Johnson of Waioli, Kauai, who sent specimens to Jesse Wedgewood Mighels in Boston; from the Johnson collection Mighels described 51 species of Hawaiian mollusks (Mighels, 1845).

Shells found in Hawaii by the missionary residents were also noted in published works and letters. James Jackson Jarves, journalist and art collector who arrived in 1837, wrote of the "numerous and beautiful . . . varieties of shells. . . . The *Cypraea madagascariensis* is found here abundantly, also fine specimens of *Perdix* [*Tonna*], Helias [*sic*], Bullae, Ovulae, *Neritina*, the *Conus Amiralis* and others less common. A small species of the chiton is also common" from Kauai (Jarves, 1838). Several shells

collected by Jarves were presented to the Boston Society of Natural History, the records of that society noting the acquisition of "specimens of Fusus, Achatina, Partula, Achatinella 3 species, Neritina, Bulla and Eulima, all from the Sandwich Islands from James J. Jarves" (Proc. Boston Society of Natural History, 1842).

Henry Dimond, who arrived with the seventh company of missionaries, wrote in 1840 to G. B. Sowerby, first of the name, that he had

> . . .paid some attention to [conchology] since I have been here about 6 years. I cannot in one letter enumerate all the different kinds of shells found here. I have collected perhaps 300 or 400 belonging to the various genera but mostly small, the most common are paper nautilus Tritons trumpet, two or three species of the Cypraea C. Mauritiana C. Madagascariensis etc. etc. The Indian Umbrella Patellas and Sottea [*sic*]. Several kinds of the freshwater Nereta peculiar to the Islands. Several kinds of the Cone are common the Tiger cone Hebrew cone etc. very fine specimens of the Solarium perspectivus and the terebra etc. Of Sand shells there are quite a variety some of them I think yet undescribed. I have found a great many small (pins head sized) shells adhering to the roots of coral and about the mouths of echini the names of which I am unacquainted with, many of them probably new . . . (Matheson, 1966).

The largest collection of shells to be assembled in the Hawaiian Islands prior to 1850 was that made by the botanist Thomas Nuttall, who, on his return to the United States, made a part of his shell collection available to T. A. Conrad of the Academy of Natural Sciences of Philadelphia from which 37 species of Hawaiian shells were described (Conrad, 1837). Unfortunately, a number of localities were mixed in this account, and several Hawaiian species *(Isognomon californicum, Brachidontes crebristriatus)* were erroneously attributed to California (see Keen, 1966).

Nuttall's name also appears as author of several species in Jay's (1839) *Catalogue,* but the names are *nomina nuda* for they were published with neither descriptions nor figures. Thus although Nuttall's name has traditionally been associated with such familiar Hawaiian species as *Cellana exarata* and *Strombus maculatus,* authorship of these species is now attributed to the first subsequent describer (Reeve, 1854, and G. B. Sowerby, 1842, respectively).

Shortly after returning to the United States, Nuttall retired to his birthplace in England. He took with him his collection of shells, and some 2,000 specimens of his "duplicate collection of Californian and Sandwich Islands shells" were purchased for the British Museum (Natural History) by the Keeper of Zoology, J. E. Gray (Nuttall letter, British Museum (N.H.)) in 1855. In 1861, 368 additional specimens were acquired by the British Museum (N.H.) from the executors of Nuttall's estate (Smith, 1906). This collection was the source of numerous descriptions and records of Hawaiian mollusks published by Arthur Adams, Lovell Reeve, and G. B. Sowerby, second of the name.

Two 19th-century travelers of lesser note who visited the Hawaiian Islands were M. Adolphe Lesson and Herr Richard Philippi. The specimens collected by Lesson were described by his brother, R. P. Lesson (1842a; 1842b), well known for his descriptions of the mollusks of the French corvette, the *Coquille*.[2] The shells collected by Philippi, a German merchant who made his fortune and home in Chile, were described by his brother, R. A. Philippi (1842-1851).

2. The *Coquille* did not visit the Hawaiian Islands during its extensive voyage around the world from 1822-1825.

The last years of the first half of the 19th century were marked by the visit of the ships of the United States Exploring Expedition. Under the able command of Charles Wilkes, the naturalists Charles Pickering, Titian R. Peale, Joseph P. Couthouy, J. D. Brackenridge, Joseph Drayton, William Rich, and the geologist J. D. Dana sailed around the world. In the Hawaiian Islands the members of the party were entertained in many a missionary household. Henry Lyman (1906), for example, wrote of "the delightful voyagers . . . Mr. Couthouy, the conchologist, Mr. Pickering . . .and Mr. J. D. Dana." Couthouy left the expedition in Honolulu because of illness, and the mollusks of the Expedition were collected by Pickering, Brackenridge, and Drayton. The collection was assembled in Washington, D. C., and the task of describing the mollusks assigned to Augustus A. Gould, who described 62 species from Hawaii. Gould's types are now in the Museum of Comparative Zoology, Harvard, and the Smithsonian Institution, United States National Museum (Johnson, 1964).

RESIDENT NATURALISTS: 1850-1900

In 1850 the sporadic reports on Hawaiian mollusks, published as a result of the miscellaneous collecting activities of voyagers, missionaries, and travelers, became less frequent, and from the Hawaiian Islands themselves there began to flow descriptions and records of mollusks. Though they were physically isolated from the centers of conchological activity in Europe and the United States, the islands were nevertheless home to several resident naturalists.

Dean of the resident naturalists was Wesley Newcomb, physician and naturalist, who, during a stay of several years (1850-1856), was not only to accumulate a collection of shells which in 1890 was "still the finest in existence" (R. E. C. Stearns, 1892), but who was also to find material which was a source of publication through the years to 1870. Supervisor of public health and active in governmental affairs, Newcomb also spent countless hours collecting land and marine shells on the islands of Oahu, Molokai, and Lanai. Hartmann (1888) wrote that Newcomb also "reared large numbers of the different species [of *Achatinella*] and observed the numerous varieties from a common ancestor." Although he collected other shells, Newcomb's first love was the family Achatinellidae, and when he returned to the United States in 1856 he arranged a trip to Europe, with A. A. Gould as his companion, to study the types of the species of *Achatinella* described by Ferussac, Swainson, and Pfeiffer. In London Newcomb met Hugh Cuming, the most famous of the English collectors, to whom he left specimens of *Achatinella* and Hawaiian marine shells.

The Newcomb collection was purchased by Ezra Cornell, founder of Cornell University, in 1868 for $15,000 (Clarke, 1960). After making arrangements for the purchase of the collection, Newcomb returned to Hawaii in 1868 to collect shells and renew acquaintances. He wrote Cornell "[I] engaged in gathering shells . . . after using my dredge in the harbor I expect to sail for Kauai. . . . Since arriving here I have been successful in obtaining several specimens of *Cypraea tessellata* and *C. sulcidentata,* both rare species. . ." (Clarke, 1960). In another letter to Cornell he told of "dredging *outside* the Harbor of Honolulu in from 10 to 30 fathoms of water" where he "obtained a species of *Modiola* entirely *new* to Science and incomparably the most beautiful of the Genus." This species was one of the two marine shells from

the Hawaiian Islands described by Newcomb in 1869 (Clarke, 1960). On his trip to Kauai, Newcomb also purchased some shells from the collection of Mrs. Johnson, whose husband had several years earlier sent shells to Mighels (Clarke, 1960).

Of perhaps even greater interest than Newcomb's published contributions to the knowledge of Hawaiian mollusks is that of his influence on other Hawaiian naturalists. A companion on his collection expeditions between 1850 and 1856 was the young missionary scion, John T. Gulick, then a student at Punahou School. In 1853 Newcomb became acquainted with the recently arrived young naturalist, Andrew Garrett, who had come from New York and settled at Hilo, Hawaii; Newcomb arranged to finance Garrett's collecting activities for several months. Evenings in Honolulu were often spent in conversation with another recently arrived naturalist, William Harper Pease, and with the French Consul, Dominique Frick, who was an ardent land shell collector.[3]

John T. Gulick was the first Hawaiian-born naturalist. Son of the Reverend Peter J. Gulick, the younger Gulick was born on Kauai in 1832. Although his first memories were "of creatures from the ocean which I must have seen at Waimea,"[4] by 1850 as a student at Punahou he was collecting land shells as assiduously as American schoolboys of that period collected butterflies (A. Gulick, 1932). His hobby led him to become one of the earliest and most respected proponents of Darwin's theory of natural selection.

Long discussions with Newcomb stimulated Gulick's interest in natural history; and extensive collecting trips with Newcomb, "the Emerson boys" (Mr. J. S. Emerson and the Reverend O. P. Emerson), and Frick resulted in a collection of material which was eventually to serve as the basis for the first extensive work on the evolution of Hawaiian land shells (J. T. Gulick, 1905). Gulick left the islands as a college student in 1853, and except for brief visits on leave from his missionary assignments in the Orient, was not to reside there again until he retired in 1906. His latter years were spent quietly at his home in Manoa, where he died in 1928.

"One of our most industrious and enterprising naturalists" (Newcomb, 1870) was William Harper Pease, who, between his arrival in the Hawaiian Islands in 1850 and his death there in 1871, described and recorded more than 300 species of Hawaiian mollusks. Pease was by profession a surveyor, and was variously employed by the government of the Hawaiian Kingdom as a tax collector and commissioner for water rights and rights-of-way. His consuming interest, however, was in mollusks, and he devoted his leisure hours and his fortune to collecting shells, amassing a conchological library with which to study his material, and to writing. Publishing in the *Proceedings of the Zoological Society of London, Journal de Conchyliologie,* and the *American Journal of Conchology,* Pease also spread knowledge of the fauna of Hawaii by means of his far-flung correspondence and exchanges.

Corresponding initially with the English shell dealer Richard Damon and with conchologists such as Hugh Cuming and P. P. Carpenter, Pease was able to write in

3. Frick published only one short paper on Hawaiian mollusks, that dealing with *Achatinella* (Frick, 1856).

4. Young J. T. Gulick's early interest in marine organisms may well have been stimulated by Thomas Nuttall and J. K. Townsend, the latter writing of the long visit with the Gulick family in 1834 and the "lively Gulick boys" (Townsend, 1839).

1869 that he had "posted myself up as to the names and addresses of all collectors throughout the world" (Pease, 1869a). He wrote regularly to Carpenter, Cuming, the Adams brothers, and J. E. Gray (see Gray, 1858) in London, to Deshayes in France, to Dunker and Dohrn in Germany, to Brazier in Australia, and to Nevill in India. The extent of his exchanges is to be seen in collections all over the world today: there are specimens labeled as from the Pease collection in the British Museum (Natural History), the Academy of Natural Sciences in Philadelphia, the Smithsonian Institution in Washington, D. C., the Australian Museum in Sydney, and the National Museum in Victoria, Australia. And to Pease are attributed specimens listed in the catalogs of Paetel (1873) in Germany, the Rigaccis (1866) in Italy, Grasset (1884) in Algeria, and Nevill (1885) in India. A small collection assembled by Pease was sent to Germany in 1869 where it was described in the *Donum Bismarckianum* (Martens and Langkavel, 1871); another was sent by the French Consul of the Hawaiian Kingdom to France to the Exhibition in Paris in 1872 (Hawaii State Archives). Pease's own collection was sold in the United States following his death in 1871 and is now in the Museum of Comparative Zoology, Harvard University.

Pease's closest friend and companion was Andrew Garrett. Writing to Garrett in 1857, Pease discussed their mutual interests and suggested that an association between them would be beneficial to both (Pease letter, Bernice P. Bishop Museum). Garrett had been a paid collector for Newcomb, and was also supported by the American conchologist John G. Anthony. In Hawaii Garrett collected materials for Pease and later continued his collaboration by providing shells and observations from other islands in the Pacific.

Garrett's work on the Hawaiian mollusks consists of a short paper dealing with 11 marine and terrestrial species (Garrett, 1857), another on terrestrial forms (Garrett, 1873c), and records of Hawaiian species in his catalogs of Pacific cowries and miters (Garrett, 1878, 1879, 1880). Garrett died in Tahiti in 1888; his collection, which was purchased by Charles R. Bishop (Kent, 1965), is now in the Bernice P. Bishop Museum, Honolulu, as are his notebooks, unpublished manuscripts, and some of his correspondence.

During the latter part of the century the conchological tradition of the early resident naturalists was continued by missionary sons, such as D. D. Baldwin (1831-1912), and Oliver (1845-1938) and Joseph S. Emerson (1843-1930). Baldwin began a shell collection about 1873 and published *A Catalogue of Fresh-water and Land Shells of the Hawaiian Islands* (Baldwin, 1893), a list of Hawaiian cowries (Baldwin, 1898) and lists and descriptions of species of *Achatinella* (Baldwin, 1887, 1895). The Baldwin land shell collection is now at Yale University and in the California Academy of Sciences; the marine shells are in the Maui Historical Society Museum, Wailuku, Maui. Baldwin and the Emersons exchanged and corresponded with conchologists all over the world; it was this exchange which provided material for the work on Hawaiian land shells of Binney, Hartman, and Hyatt in the United States, Boettger in Germany, and Ancey and Crosse in France.

THE TURN OF THE CENTURY: EXPEDITIONS AND PROJECTS

Two ships which visited Hawaiian waters at the turn of the century provided the first records of deep-water mollusks in the islands. The British Expedition's *Challenger* arrived in May, 1876, and from a single dredge haul at a depth of 40 fathoms

"off the reefs of Honolulu" 43 species of bivalves and gastropods were described or recorded by Smith (1885) and R. B. Watson (1886), respectively. In other volumes of the *Challenger* the opisthobranchs were described by Bergh (1884b), the pteropods by Pelseneer (1888), and the cephalopods by Hoyle (1886). The *Challenger* collections are in the British Museum (Natural History).

The U. S. Fish Commission ship *Albatross* undertook a systematic exploration of Hawaiian waters between 1891 and 1902, occupying 397 deep-water stations in the island chain. The cephalopods collected during the expedition were monographed by Berry (1909, 1913, 1914), the pelecypods were included in Dall, Bartsch, and Rehder's (1938) monograph of Hawaiian bivalves, and six species of gastropods were described by Dall (1895, 1924). The *Albatross* collections are in U. S. National Museum in Washington, D. C.

The turn of the century was also marked by a joint project undertaken by Bishop Museum in Honolulu and the Royal Society and the British Association for the Advancement of Science in England. The project resulted in the publication of the *Fauna Hawaiiensis* (Sharp, 1899-1913); a section on the Mollusca by E. R. Sykes (1900) treats largely of the terrestrial and freshwater mollusks.

Dr. Schauinsland, director of the Bremen Museum, spent three months on Laysan between 1896 and 1897, primarily collecting fish and birds, but three nudibranchs which he found were discussed by Bergh (1900), and the cowries were analyzed by Schilder (1933). The Schauinsland collections are now in the State Museum of Vienna.

BERNICE P. BISHOP MUSEUM

Founded in 1889 to safeguard the Hawaiian and Polynesian antiquities in the collection of Princess Bernice Pauahi Bishop, Bishop Museum in 1896 became "a scientific institution for collecting, preserving, storing, and exhibiting specimens of Polynesia and kindred antiquities, Ethnology, and Natural History . . . . and for the examination, investigation, treatment and study of said specimens" (Kent, 1965).

The first conchological acquisition of the Museum was the Garrett collection purchased in 1894 (Kent, 1965). Because there was no professional conchologist in Hawaii, the Museum Trustees invited William Healy Dall, Honorary Curator of the Division of Mollusks and Tertiary Fossils in the United States National Museum, to visit Honolulu in 1899. Dall was acquainted with both Garrett and Hawaiian shells: in 1866 he had written Garrett complimenting him on his collecting activities and asking for "minute or land mollusca from the Pacific" (Dall letter, Bishop Museum); in 1893 he disputed the late W. H. Pease's interpretation of the Hawaiian limpets, denying that species could be distinguished as Pease had distinguished them on the basis of color, smell, and taste (Dall, 1893); and he had described some of the mollusks dredged by the *Albatross* (Dall, 1895).

During a visit in April and May, 1899, Dall arranged and cataloged the Garrett collection (Dall, 1900a) and was made Honorary Curator of Bishop Museum. He also developed an abiding interest in Hawaiian natural history, an interest reflected in a series of papers on the geology of Oahu (Dall, 1900b, 1901, 1904, 1911), Hawaiian marine mollusks (Dall, 1913, 1919, 1921, 1923, 1924), Physidae (Dall, 1903) and the monograph of Hawaiian bivalves (Dall, Bartsch, and Rehder, 1938). A companion volume on the gastropods was left in manuscript form on his death in 1927.

The Islands' first resident professional conchologist was appointed to the Museum staff in 1907. C. M. Cooke, Jr. (1874-1948) was the son of a missionary family and had spent his youth in pursuit of land shells on Oahu. He received his Ph.D. at Yale University under the direction of the zoologist Addison E. Verrill. Joining the staff as an assistant in 1902, it soon became apparent that Cooke's interest and training were admirably suited to the position of Curator of Pulmonates, a post he held until his death in 1948.

Cooke shared his interest in Hawaiian land shells with Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia. The two conchologists began to collaborate about 1900, and several volumes of Tryon's *Manual of Conchology* are co-authored by Pilsbry and Cooke (1912-1920). Pilsbry visited the islands in 1913 and again in 1920. He was appointed consulting malacologist of Bishop Museum in 1940. Pilsbry was also interested in marine mollusks, and his early papers on Hawaiian marine shells in collaboration with C. M. Vanatta (1905, 1908) and Elizabeth Letson Bryan (1918) were the forerunners of an eight-part series authored by Pilsbry himself (Pilsbry, 1917-1921).

Much of the material on which Pilsbry worked, both terrestrial and marine, was that collected by an amateur conchologist resident in Hawaii, Ditlev Thaanum (1867-1963). Thaanum arrived in Hilo, Hawaii, from Denmark in 1894, and began to collect marine and terrestrial mollusks as a hobby. During the course of his long and active life he collaborated with his brother-in-law, D. B. Langford, in building up an unparalleled collection of Hawaiian and Pacific material. The land shell collection was presented to Harvard University in 1953. During the 1920's and 1930's portions of the marine collection were given to the Academy of Natural Sciences of Philadelphia, the United States National Museum, the Field Museum of Natural History in Chicago, the Museum of Comparative Zoology at Harvard, and the Museum of Zoology at Michigan. Bishop Museum received the great bulk of his collection on his death in 1963. This last collection is important not only for the extensive series contained within it, but also for type and paratype materials from such correspondents as G. B. Sowerby, third of the name, H. C. Fulton, W. H. Dall, and H. A. Pilsbry. Thaanum maintained elaborate catalogs and notes on his collection, and published two short notes on Hawaiian mollusks (Thaanum, 1921, 1927).

Although Cooke as Curator of Pulmonates was primarily interested in land shells, other members of the Museum staff were interested in marine mollusks. The ornithologist William Alanson Bryan (1875-1942), working with his wife, Elizabeth Letson Bryan (1874-1919), who was herself a conchologist, amassed a large collection of marine shells. An annotated catalog prepared by the Bryans served as the basis for the first summary account of Hawaiian marine mollusks, the two chapters on Hawaiian shells in Bryan's (1915) monumental *Natural History of Hawaii*. Bryan also published a note on the bivalve *Tapes philippinarum* (Bryan, 1919). Some of the Bryan collection is now in Bishop Museum; a portion was purchased by C. A. Allen in 1924 (Weaver, 1964a).

C. H. Edmondson, appointed Invertebrate Zoologist in 1920, also contributed to the growing literature on Hawaiian marine mollusks. His molluscan papers deal with the wood-boring bivalve *Teredo* and other fouling organisms, and his chapter on mollusks in the *Reef and Shore Fauna of Hawaii* (Edmondson, 1933, 1946a) contains a more extensive account of Hawaiian marine shells than that of Bryan.

Edmondson encouraged the work of J. M. Ostergaard (1878-1969) and W. M. Ingram (1913-1967) between 1930 and 1950. Ostergaard began work with fossil mollusks, stimulated by Dall's geological studies, and recorded numerous fossils on Oahu, Maui, and Molokai (Ostergaard, 1928, 1937, 1939). Ostergaard's later work deals with spawning in gastropods (Ostergaard, 1950), and opisthobranchs (Ostergaard, 1955). Ingram collaborated with Edmondson on fouling studies (Edmondson and Ingram, 1939, Ingram, 1939c) and worked on the cowries in Bishop Museum (Ingram, 1936, 1937, 1939a, 1939b, 1943, 1947).

THE HAWAIIAN MALACOLOGICAL SOCIETY

One of the most potent forces in the accumulation of information on Hawaiian marine mollusks in this century has been the Hawaiian Malacological Society. Founded in 1924 as the Hawaiian Conchological Club by Thaanum and C. F. Mant, the shell club has since 1952 published a monthly bulletin which includes not only news of Hawaiian shells, but also that of mollusks from all over the world.

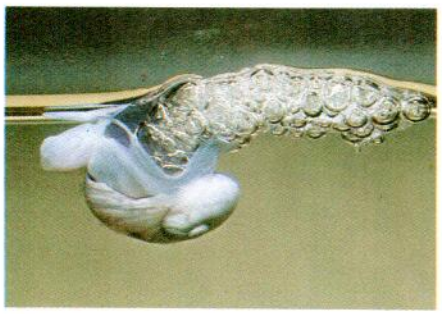
A

B

C

D

E



F

Figure 6.—Life styles of some prosobranchs. A. Opihi *(Cellana exarata)* on a rocky shoreline. B. *Hastula hectica* in sand. C. *Neothais harpa* feeding on *Nerita picea*. D. *Serpulorbis variabilis* in a tide pool. E. *Littorina pintado* clustered on a rocky shore. F. *Janthina* sp. with gas float on the surface of the ocean. (B by O. Schoenberg; F by I. Bennett.)

PHYLUM MOLLUSCA

THE MOLLUSKS are an ancient group, second only to the Arthropoda in age and numbers of species among Recent animal phyla. They are among the most diverse of all animals in form, structure, and habitat. Their distinguishing features are a discrete visceral mass, composed of digestive, reproductive, and excretory systems, and a muscular head-foot complex. Over the visceral mass lies a fold of the body wall, the mantle, which secretes the shell in many mollusks.

Although the shell of mollusks is the feature by means of which the group is most often recognized, the name of the phylum is derived from the Greek word "mollis," meaning "soft," and, indeed, the classes of mollusks are distinguished by names which refer to features of these animals other than a shell. Four of the most often recognized classes are distinguished by reference to the foot, the Gastropoda ("stomach foot"), the Pelecypoda ("hatchet foot"), the Cephalopoda ("head foot"), and the Scaphopoda ("boat foot"). Three classes are not so well known, and are named for shell plates which are present or absent on the dorsum: the Polyplacophora ("many-plate bearers") which include the chitons, the Monoplacophora ("one-plate bearer") which include the "living fossil" *Neopilina*, and the Aplacophora ("no-plate bearer"), an obscure group of wormlike creatures. All except the monoplacophorans have been reported from the Hawaiian Islands.

Class GASTROPODA

The gastropods are so-called because of their large visceral mass, either spirally coiled or flat, which is piled atop the foot. Typically the visceral mass and the head-foot are contained in a spirally wound shell, but there are many gastropods without shells. The major divisions of the class are based on differences in their modes of breathing: the Prosobranchia, in which the gills lie over the head; the Opisthobranchia, with the gills on the back or at the side; and the Pulmonata, in which the mantle cavity is vascularized and lunglike. The Prosobranchia are separated from the Opisthobranchia and Pulmonata by the form of the nervous system. In the prosobranchs the nerve cords are twisted into a figure eight and they are sometimes called the Streptoneura, distinct from the Opisthobranchia and Pulmonata or Euthyneura in which the nerve cords are straight.

Subclass PROSOBRANCHIA

The hallmark of the prosobranchs, as their name implies, is their front-directed gills, or, more broadly interpreted, their frontally directed mantle cavity. The arrangement develops during their life history when, through the process of torsion, during an

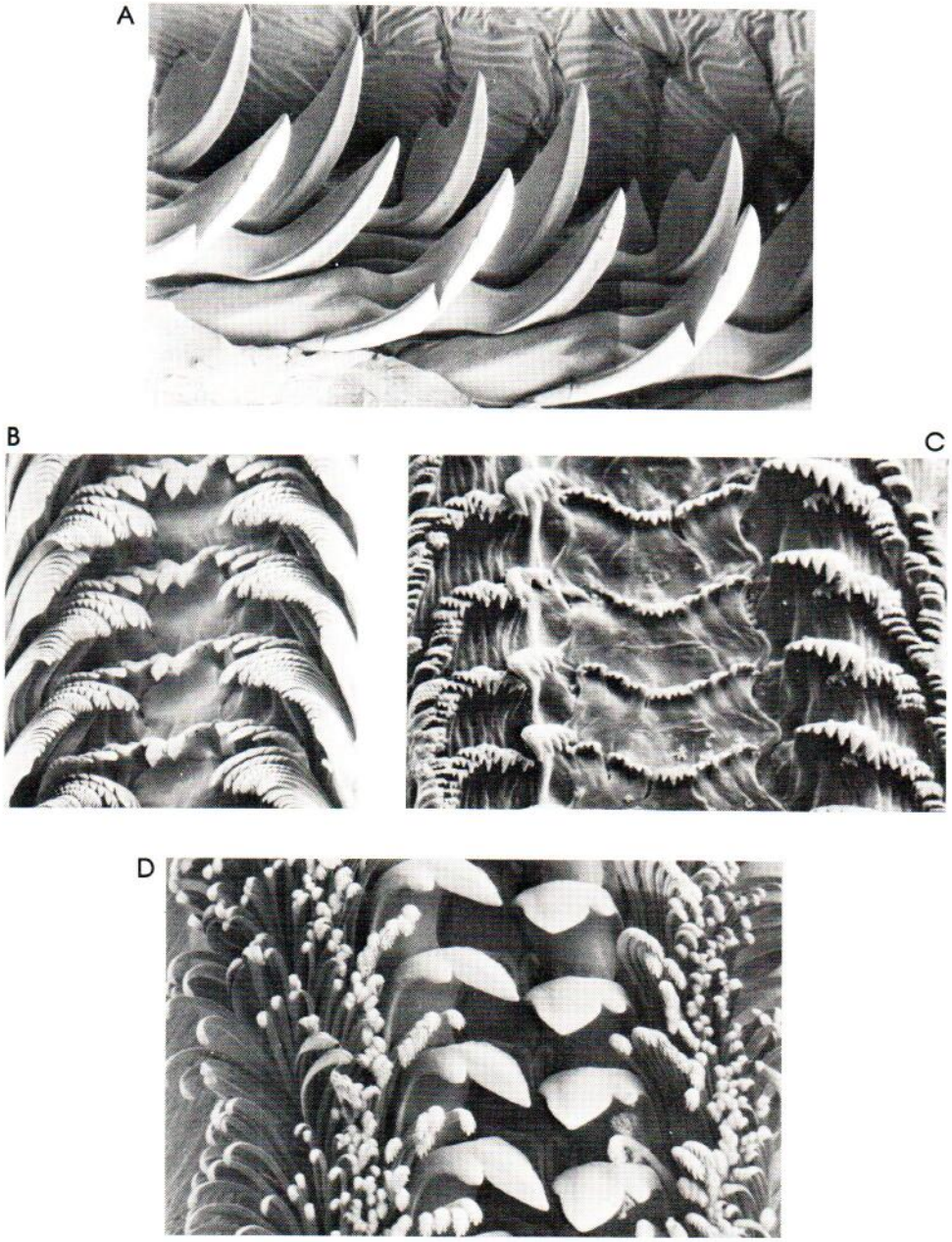


Figure 7.—Scanning electron microscope photographs of radulae. A. Docoglossate radula of *Cellana exarata*, 160X. Rhipidoglossate radulae of B. *Tricolia variabilis*, 380X. C. *Sinezona insignis*, 1500X. D. *Diodora granifera*, 160X.

early stage in larval life, a posteriorly directed anus and gills are rotated 180° counterclockwise so that they come to lie above and behind the head. The result has been a highly successful group of animals which have come to occupy a variety of habitats. Some of their different life styles are shown in Figure 6.

The very large group of mollusks with this anatomical orientation has been variously subdivided. In one such scheme are the Diotocardia or Archaeogastropoda, animals in which there are usually two sets of organs in the mantle cavity, and the Monotocardia (Mesogastropoda and Neogastropoda) in which the primitively paired organs of the mantle cavity are reduced to single structures.

The prosobranchs have also been classified on the basis of the features of the radula, the ribbon to which are affixed chitinous teeth or plates in the mouth, and a structure peculiar to the mollusks. In the Patellidae the radula is docoglossate, consisting of transverse rows of a few strong teeth (Fig. 7A). In the Fissurellidae, Trochidae, Turbinidae, and Neritidae the radula is rhipidoglossate, with a large number of marginal teeth, few lateral teeth and a single central tooth (Fig. 7 B, C, D). The most common type of radula is the taenioglossate radula of the Mesogastropoda, with seven teeth in each row, one central flanked on each side by one lateral and two marginals (Fig. 22). In the Muricidae, Buccinidae, and others of the neogastropods the marginals are spinelike and the radula is termed rachiglossate (Fig. 84). The most peculiar radula is that of the Conacea in which there may be only a single barbed tooth (Fig. 120).

For purposes of identification, the shell is the most often utilized structure among the parts of a gastropod. The various parts of the shell, especially those referred to in the text, are shown in Figure 8.

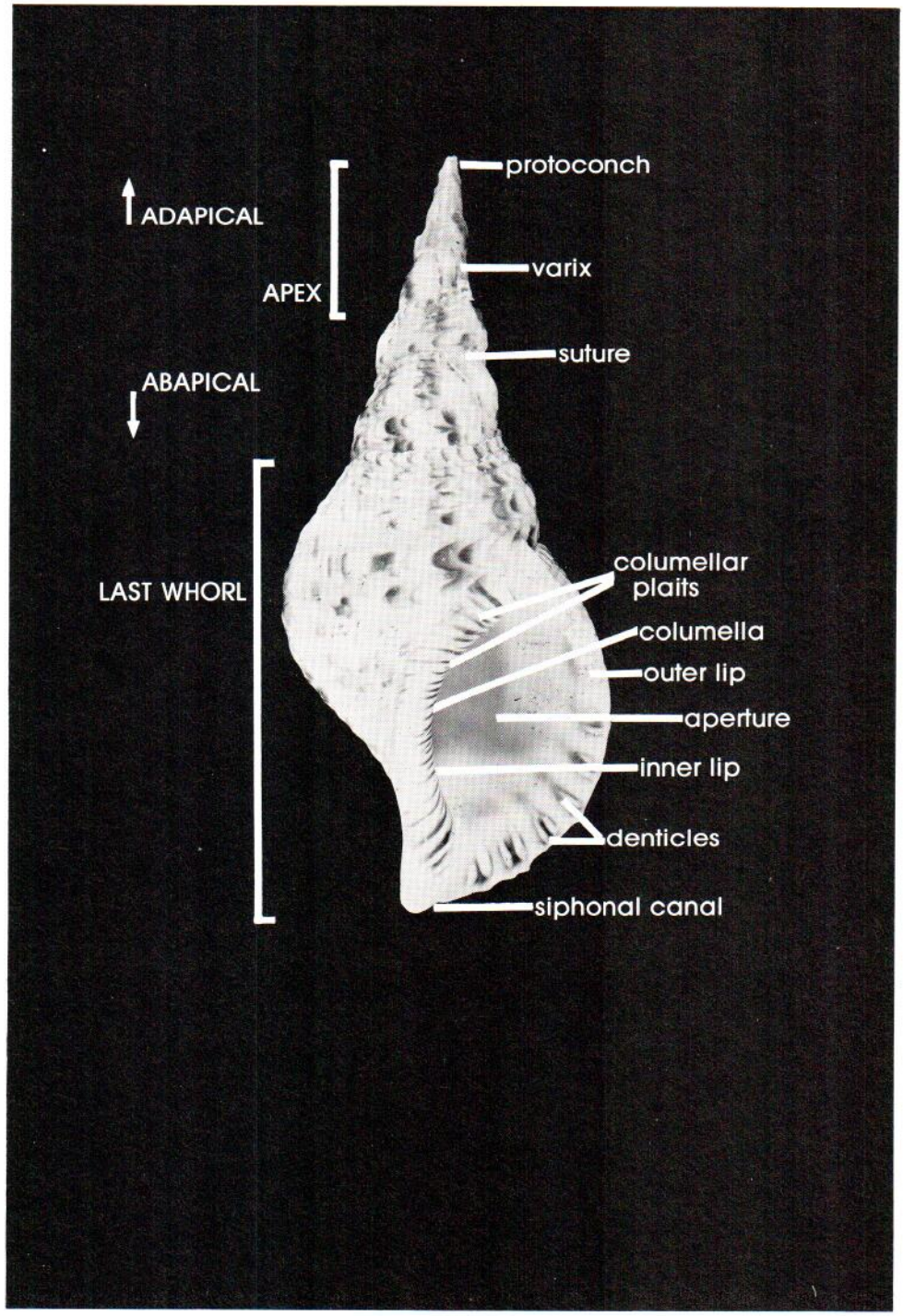


Figure 8.—The parts of a gastropod shell.

Order ARCHAEOGASTROPODA

(Diotocardia)

The archaeogastropods are among the least specialized of the prosobranch gastropods, and apparently among the oldest of the living forms. There are two shell types, limpetlike, conical, wide-apertured shells in the Pleurotomariacea, Fissurellacea, and Patellacea, and more or less spiral shells in the Trochacea and Neritacea.

Except for some members of the highly specialized Neritacea, the archaeogastropods are marine. Typically the mantle cavity complex has two ctenidia, two kidneys, and two auricles, but there are many intermediate forms. The ctenidia are "aspidobranch," or bipectinate, with the filaments alternating on two sides of the gill axis and free at the front end.

Archaeogastropods have traditionally been described as herbivores and deposit scrapers, but a carnivorous habit has been described in several. *Diodora* and *Emarginula* in Britain feed on sponges (Graham, 1939), *Megatebennus bimaculatus* in California feeds on colonial ascidians (Ghislin in Perron, 1975), and the California trochids *Calliostoma annulatum* and *C. variegatum* are facultative predators on hydroids (Perron, 1975).

Fertilization is external except in the neritaceans. The gametes are shed into the water or deposited in clumps supported by a jellylike matrix. The eggs are small and develop into trocophore larvae within a few days. Development is direct, or there is a veliger stage lasting only two or three days (J. B. Taylor, 1975).

Superfamily PLEUROTOMARIACEA

Family **Scissurellidae**

The Pleurotomariacea represent the presumably oldest and most primitive of living gastropods, characterized by paired retractor muscles and ctenidia of the early mollusks. The superfamily includes not only the famous trochiform shells of *Mikadotrochus* of the Pleurotomariidae and the commercially important ear-shaped shells of the Haliotidae or abalones, but the minute, turbiniform shells of the Scissurellidae, the only pleurotomarid family represented in Hawaiian waters. Pleurotomarid shells are perforated by slits or holes.

Scissurellid shells are white, with a few rapidly increasing whorls and a large umbilicus. The most noticeable feature is the slit on the last whorl, an open channel in the outer lip in *Scissurella* and a small foramen in *Sinezona*. The operculum is round and multispiral; there is a central nucleus. The sculpture is reticulate, of axial ribs or threads. There are two shell muscles of equal size.

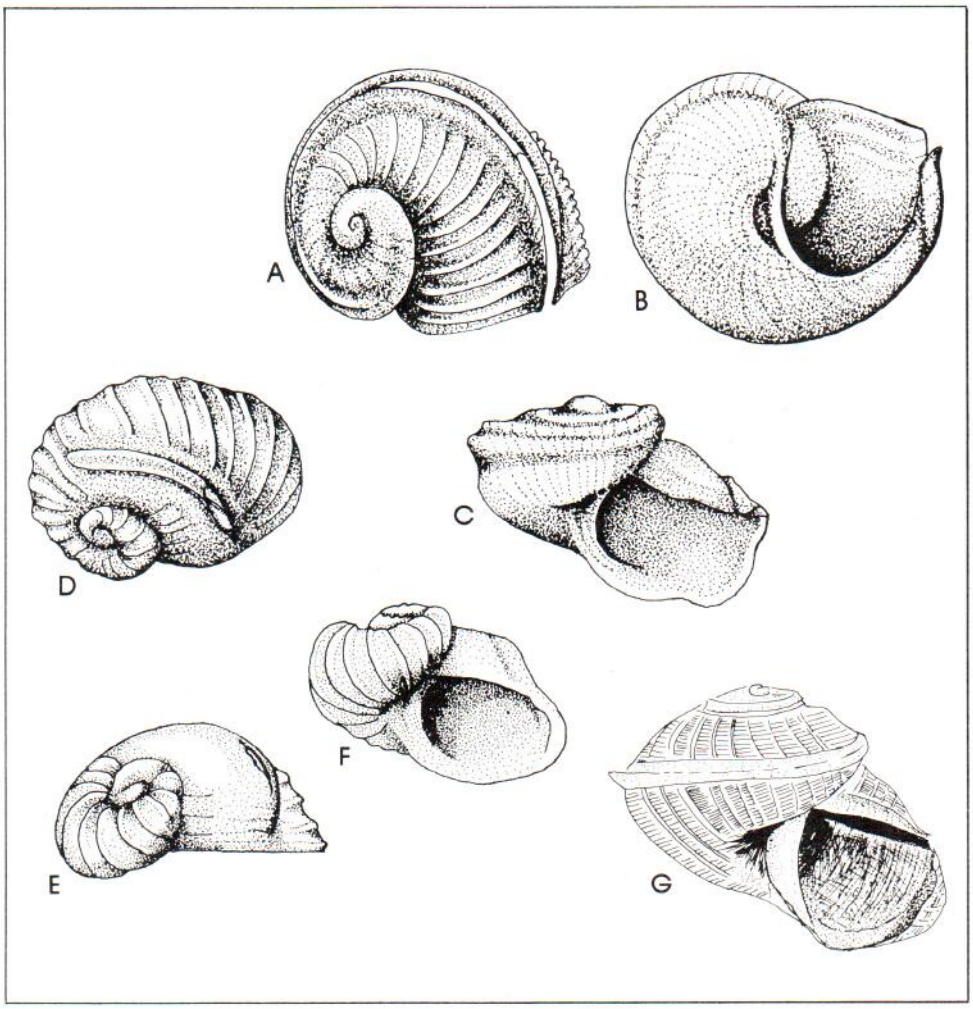


Figure 9.—**Scissurellidae.** A, B, C. *Scissurella pseudoequatoria*, diameter, 0.9 mm. D, E, F. *Sinezona insignis*, diameter 0.7 mm. G. *Scissurella lamellata*, diameter 3.5 mm.

Scissurella lamellata (A. Adams, 1862). Fig. 9 G. Height, 1.5 mm; diameter, 2 mm. *Shell:* turbinate; thin; white; periphery of last whorl with a strong carina, the edges sharply raised; slit terminal, open about one-fifth of the last whorl. *Sculpture:* prominent, broadly spaced axial ribs and crisp spiral threads in the interspaces between the ribs. *Aperture:* rounded, oblique; outer lip thin; inner lip slightly reflected; umbilicus deep.

These scissurellids are common in dredge hauls at depths of more than 100 m.

S. lamellata was described from depths of 52 to 142 m from Mino-Sima and O-sima, Japan, and has since been reported from the Pacific coast of Japan at depths of 224 to 283 m (Kuroda and Habe, 1952) and from Alaska at depths of about 50 m (McLean, 1967).

Scissurella pseudoequatoria Kay, new species. Fig. 9 A-C. Height, 0.5 mm; diameter, 0.9 mm. *Shell:* turbinate, depressed, thin; periphery of last whorl bordered by a strong carina leading to a slit, the edges of which are slightly reflected and frilled; whorls above carina slightly convex, below carina concave, remainder of last whorl concave. *Sculpture:* minute, close-set curved ribs more distinct above carina than below, and with obscure spiral threads. *Aperture:* subquadrate, oblique, inner lip slightly reflected; umbilicus narrow, partly shielded by inner lip.

These scissurellids are found with *Sinezona insignis* in tide pools, on solution benches, and occasionally in sediments to depths of 30 m.

Type locality: Hilo, Hawaii on algae in the intertidal zone, May 8, 1970. *Holotype:* Bernice P. Bishop Museum No. 9740. *Paratypes:* Australian Museum, United States National Museum, British Museum (Natural History).

The shells are distinguished from those of other Indo-West Pacific scissurellids by their small size and depressed outline. They resemble the shells of *S. equatoria* Hedley, 1899, from Funafuti in sculpture but the shells of that species are larger (3 mm in diameter) and more inflated. Derivation of name: *pseudein*, Greek — to deceive. Refers to superficial resemblance to *S. equatoria*.

S. kayae Geiger + McLean, 2010

(=*Sinezona insignis* (Smith, 1910). Figs. 7 C; 9 D-F. Height, 0.6 mm; diameter, 0.9 mm. *Shell:* turbinate, convex, thin; periphery of last whorl bordered by a strong carina with erect edges and with a slit in varying positions on the last whorl from midway on the carina to nearly terminal; three rapidly enlarging whorls which are convex except for the area just below the carina on the last whorl where there is a concave depression; suture distinct. *Sculpture:* strong, curved axial ribs most prominently developed on the last whorl, becoming obsolete near the aperture; entire shell roughened by fine spiral threads. *Aperture:* ovate, oblique; umbilicus moderately wide and deep. *Color:* white.

Habitat: This scissurellid is a weed-dweller, found on algae such as *Valonia, Halimeda,* and *Cladophoropsis* on basalt benches, solution benches, and in tide pools. Shells occur occasionally in sediments to depths of 30 m.

S. insignis was described from South Africa. In shape and sculpture the shells resemble those of *Scissurella coronata* Watson, 1886, but that species is a *Scissurella* with an open slit on the outer lip and the shells are larger (2.0 mm in diameter). *S. insignis* is distinguished from *S. rimuloides* (Carpenter, 1865) from the west coast of the Americas by the spiral lirae on all the whorls (McLean, 1967).

Superfamily FISSURELLACEA

Family **Fissurellidae**

This superfamily comprises a single family, the members of which bear shells with a fissure that may be in the form of an apical aperture, a marginal slit or notch, or a sinuation. The fissure is part of the mechanism by means of which the mantle cavity is ventilated. Water enters around the head, washes over the gills, the excretory

openings and the anus, and leaves the mantle cavity by way of the slit in the shell. The fissure may restrict these gastropods to a subtidal habitat, for such an opening would cause an animal exposed to the air to become desiccated.

Fissurellid shells are limpetlike, and the surface is cancellated by radiating ribs and spiral cords. The interior is porcelaneous. There is a horseshoe-shaped muscle scar which opens anteriorly.

KEY TO SPECIES OF FISSURELLIDAE FOUND IN HAWAII

1. With an apical aperture or marginal slit 2
   Shell entire, elliptical, concave in profile, white ..... *Tugali oblonga*
2. With apical aperture 3
   With marginal slit 5
3. Radial ribs numerous (20 or more) and interspaces equal in diameter 4
   Radial ribs few (12 to 14), separated by wide interspaces ..... *Diodora octagona*
4. Small (8 mm), fissure oval, margins thin ..... *D. granifera*
   Of moderate size (20 mm), fissure tri-cleft, margins thick and crenulate ..... *D. ruppelli*
5. Conical, with fine radiating ribs ..... *Emarginula hawaiiensis*
   Depressed with coarse radiating ribs ..... *E. dilecta*

Diodora granifera (Pease, 1861c). Figs. 7 D; 11 A-B. Length, 8 mm; diameter, 5 mm; height, 4 mm. *Shell:* conical, apex barely on the anterior slope; fissure elongate; margin thin; with numerous fine, nodular ribs; green and white. *Sculpture:* 30 or more equally spaced, rounded ribs radiating to margin with interspaces of equal diameter; spiral cords of lesser diameter than ribs, forming nodules where they intercept the ribs. *Color:* variable — gray-green, white, or gray or white with dark green rays; interior white or green.

These fissurellids are common, attached to the undersurfaces of rocks and rubble in tide pools, on benches, and on fringing reefs. A few shells were dredged by the *Albatross* at depths of from 90 to 100 m. Development is direct (Fig. 10).

D. granifera may range throughout the Pacific: shells resembling those from the Hawaiian Islands have been seen from the Tuamotus and are reported from Clipperton Island (Hertlein and Allison, 1966). Fossils possibly referable to the species are found in post-Tertiary beds at Enewetak, Marshall Islands (Ladd, 1966).

Diodora octagona (Reeve, 1850). Fig. 11 E, F. Length, 12 mm; diameter, 8 mm; height, 5 mm. *Shell:* conical-depressed; apex barely on the anterior slope; fissure oval; margin thick and crenulate; with a few coarse ribs; white splashed with brown. *Sculpture:* 12 to 14 primary radiating ribs extending beyond the margin and two to three secondary ribs in the interspaces terminating on the margin; spiral cords subequal

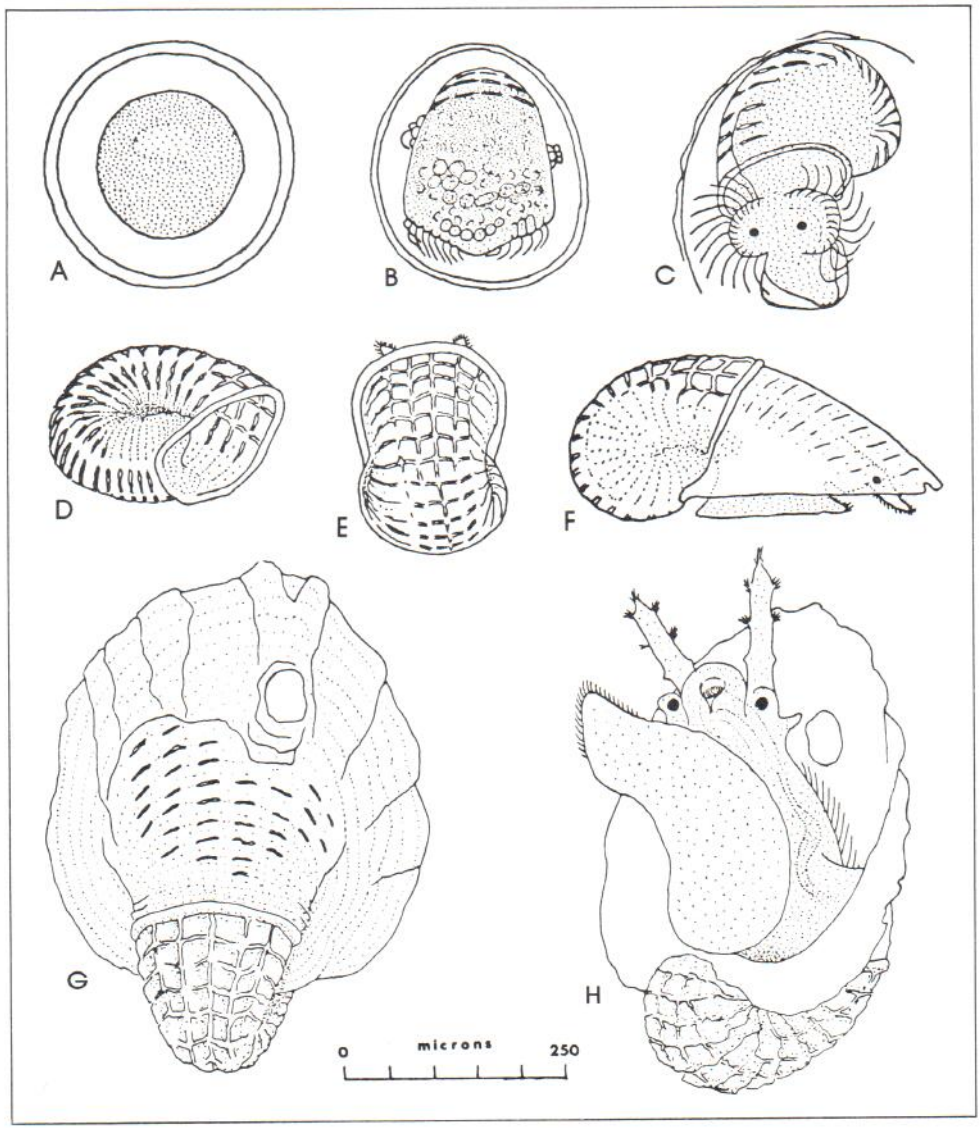


Figure 10.—Development of *Diodora granifera*. A. Mature ovum in egg capsule. B. One-day-old larva in capsule. C. Three-day-old larva leaving capsule. D. Shell of three-day-old larva. E. Dorsal view of four-day-old benthic larva. F. Two-week-old larva with marginal slit. G. Shell of a three-week-old larva showing opening on anterior slope. H. Ventral view of three-week-old larva. (After Boggs, 1977.)

in diameter to secondary ribs, forming scabrous nodules where they intercept the ribs. *Color:* variegated brown and white; interior white.

Occasional specimens are found under rocks in shallow waters and shoreward on fringing reefs.

D. octagona is widespread in the Indo-West Pacific, occurring from Ceylon through the Pacific.

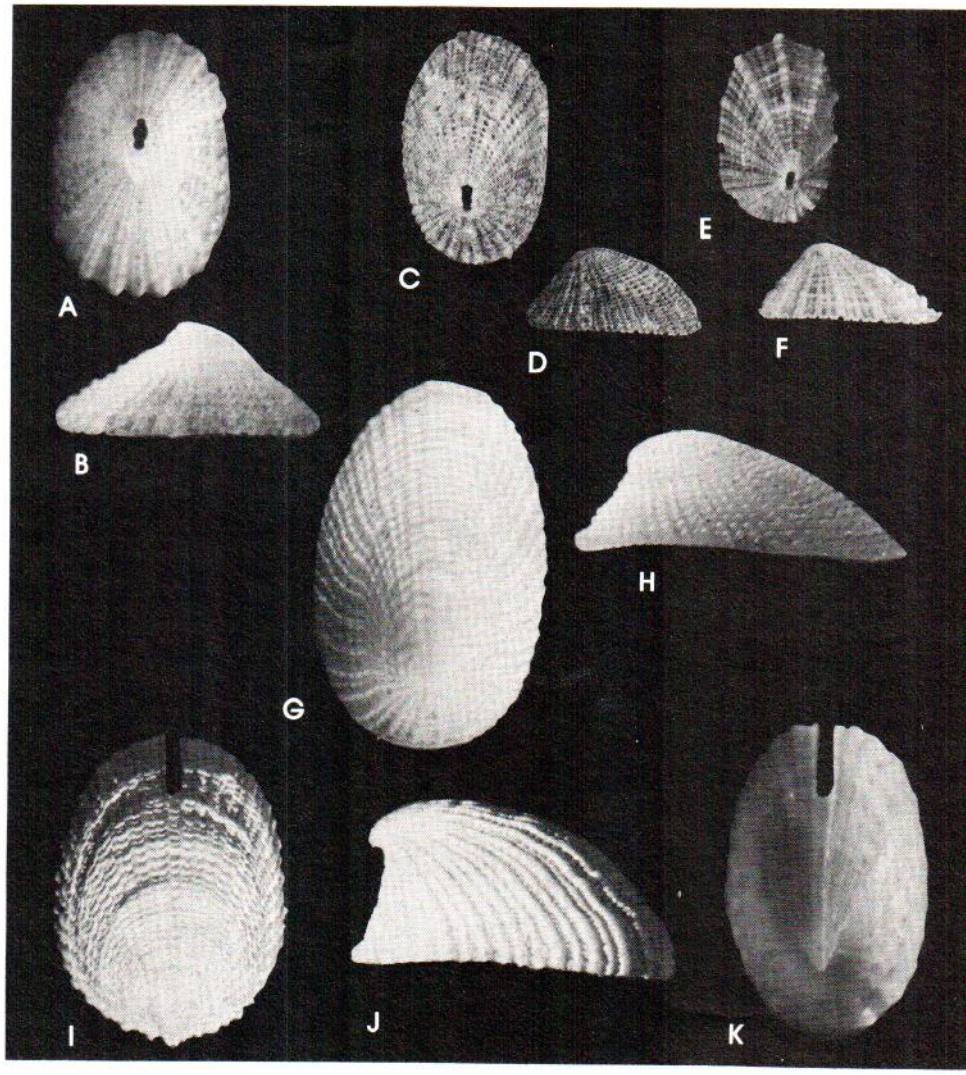


Figure 11.—**Fissurellidae.** A, B. *Diodora granifera,* length 4 mm. C, D. *D. ruppelli,* length 20 mm. E, F. *D. octagona,* length 12 mm. G, H. *Tugali oblonga,* length 13 mm. I, J. *Emarginula hawaiiensis,* length 13 mm. K. *Emarginula dilecta,* length 4 mm.

Diodora ruppelli (Sowerby, 1834). Fig. 11 C, D. Length, 20 mm; diameter, 13 mm; height, 8 mm. *Shell:* conical, convex; apex decidedly anterior; fissure tri-cleft; margin thick and crenulate; with numerous fine nodular ribs; white splashed with black. *Sculpture:* 25 to 30 equally spaced ribs radiating to the margin with interspaces of equal diameter; spiral cords of lesser diameter crossing the ribs as scabrous belts. *Color:* white with triangular black marks.

Shells were first reported on Oahu in 1962 from the reef near the entrance to the Pearl Harbor channel; specimens have since been recorded at depths to 15 m.

D. ruppelli was described from the Red Sea and apparently occurs throughout the Indo-West Pacific.

Emarginula dilecta A. Adams, 1852a. Fig. 11 K. (Synonyms: *Emarginula clathrata* Pease, Sowerby, 1866; *E. subclathrata* Pilsbry, 1890; *E. peasei* Thiele, 1915.) Length, 4 mm; diameter, 3 mm; height, 1.5 mm. *Shell:* conical-depressed; apex posterior; marginal slit short; with widely spaced nodular ribs; white. *Sculpture:* 18 to 20 widely spaced radiating ribs crossed by smaller spirals forming nodules at the junctions; interspaces microscopically cancellate. *Color:* white.

This species is known from five or six shells found in sediments at depths of 5 m off reef fronts on Oahu and from coral communities on Maui and Hawaii. Shells appear to be more common on Midway, where they are not infrequently encountered in beach drift.

E. dilecta occurs throughout the Indo-West Pacific from the east coast of Africa to the Philippines and southern Japan.

Emarginula hawaiiensis Dall, 1895. Fig. 11 I, J. Length, 13 mm; diameter, 9 mm; height, 8 mm. *Shell:* conical; apex posterior; marginal slit occupying one-third of anterior slope, trough convex; with fine radiating ribs; gray-white. *Sculpture:* 20 to 25 thin, sharp radial ribs crossed by fine concentric threads; interspaces subequal to the ribs. *Color:* gray-white.

This species was described from specimens dredged by the *Albatross* at a depth of 226 m; occasional shells have since been dredged at depths of less than 100 m.

E. hawaiiensis was described from the Hawaiian Islands.

Tugali oblonga (Pease, 1861b). Fig. 11 G, H. Length, 13 mm; diameter, 8 mm; height, 3 mm. *Shell:* narrowly elliptical, depressed, apex posterior; margin concave, with an inconspicuous indentation posteriorly; white. *Sculpture:* minutely granular radiating ribs crossed by spiral threads, the interspaces cancellated by concentric, raised striae. *Color:* white.

These limpets occur subtidally at depths of from 3 to 200 m; beachworn shells are infrequently found in drift. The eggs are incubated in the mantle cavity, a feature also reported for some temperate members of the Fissurellidae.

This species appears to be endemic to the Hawaiian Islands. In shape and sculpture, the Hawaiian shells resemble those of *T. parmophoidea* (Quoy and Gaimard, 1834), which is widely distributed in the Indo-West Pacific, but the shells of *T. oblonga* are consistently smaller than the 25-mm-long shells of *T. parmophoidea*.

Superfamily PATELLACEA

Family **Patellidae**

The members of the Patellacea, commonly called limpets, comprise a group of mollusks with symmetrical, conical shells, and a broad foot. Most patellids live along exposed, rocky, surf-swept shorelines where they may be exposed to the air for several hours at a time. The gills in these limpets differ from those typical of most prosobranchs: instead of ctenidia there is a series of secondary gills which encircle the

mantle skirt and over which water flows supplying oxygen. The gametes are shed into the water, fertilization is external, and the veligers are small, indicating a short planktonic life. Three families are included in the Patellacea, but only representatives of the Patellidae occur in Hawaiian waters.

The Hawaiian limpets are called "opihi," and the native Hawaiians distinguished three kinds: *kō'ele (Cellana talcosa),* the largest, with a yellow foot which occurs at depths of 1 to 10 m; *'alinalina (C. sandwicensis),* also with a yellow foot, but living on calcareous algae at the water's edge where the surf breaks; and *maka-ia-uli (C. exarata)* with soft, dark meat which lives higher on the rocks than *'alinalina* (Pukui, pers. comm.).

Four species are recognized here; all are apparently endemic to the Hawaiian Islands. Within the Hawaiian Island chain opihi are restricted in their occurrence to the shorelines of volcanic islands. No opihi has been reported from Kure, Midway, Pearl and Hermes Reef, or the calcareous shoreline of French Frigate Shoals, although *C. exarata* is found at La Perouse Pinnacle, a volcanic remnant within the lagoon at French Frigate Shoals.

Cellana exarata (Reeve, 1854). Fig. 7 A; 12 A-C. (Synonym: *Patella undatolirata* Reeve, 1854; *Helcioniscus exaratus* Nuttall, Dall, 1871.) Length, 40 mm; diameter, 40 mm; height, 17 mm. *Shell:* conical, slightly broader posteriorly than anteriorly; apex subcentral. *Sculpture:* close-set radiating ribs interspersed with finer ribs; ribs not projecting beyond shell margin. *Color:* dark gray, ribs usually black; interior blue-white; spatula gray or black. *Animal:* foot and mantle gray or black.

C. exarata is found on basalt shorelines from the spray zone where it occurs with the nerite, *Nerita picea,* and the algae *Ahnfeltia, Rhizoclonium,* and *Ulva* seaward to the calcareous algal zone where it intermingles with *C. sandwicensis* and the sea urchin *Colobocentrotus atratus.* Correa (1969) suggests that rapid movement and the ability to raise the shell and ventilate the mantle cavity are both factors which enable this species to live in a more fluctuating environment than does *C. sandwicensis.* In the higher regions of its distribution, the opihi have fixed home scars, indicated by clusters of animals which persist from month to month on boulders, and by grazed areas around the shells. The scars are not deep as they are in patellids elsewhere, but are merely grazed sections of the substrate.

The sexes are separate, fertilization is external, and the nonfeeding larvae may settle in three or four days after fertilization (Helfrich, 1971). The limpets settle at about 1 mm in length, and grow at rates of about 5 mm per month until they are mature (about 25 mm in length), when growth slows to about 2 mm per month. Spawning probably occurs primarily about December and January and recruitment is most noticeable from March to June.

C. exarata has been recorded as far north as French Frigate Shoals in the leeward islands where it is found on La Perouse Pinnacle, but not on the calcareous shoreline of the atoll itself.

Cellana melanostoma (Pilsbry, 1891). Fig. 12 G, H. Length, 52 mm; diameter, 43 mm; height, 37 mm. *Shell:* high-conical to flattened; apex central. *Sculpture:* strong radiating ribs which in some specimens may be scabrous; ribs not extending beyond

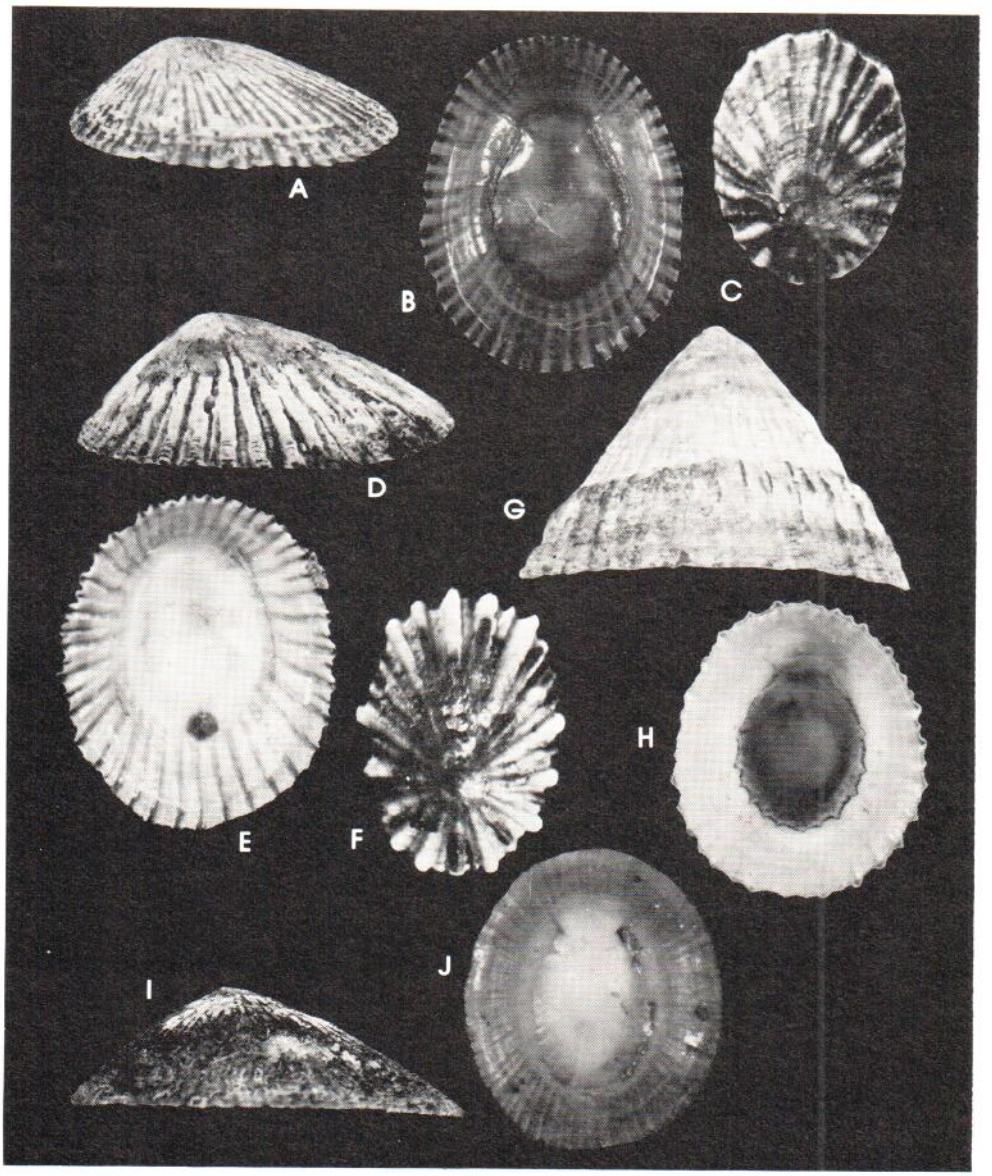


Figure 12.—**Patellidae.** A, B. *Cellana exarata*, length 20 mm. C. *C. exarata* juvenile, length 8 mm. D, E. *C. sandwicensis*, length 30 mm. F. *C. sandwicensis* juvenile, length 7 mm. G, H. *C. melanostoma*, length 40 mm. I, J. *C. talcosa*, length 40 mm.

margin of shell. *Color:* white, sparsely flecked with brown, especially in juvenile specimens; interior iridescent golden yellow, occasionally green; spatula brown or black. *Animal:* mantle and foot bright green.

This is the dominant species in the genus at Gardner Pinnacles, La Perouse Pinnacle, Necker, and Nihoa, and specimens are occasionally collected on Kauai

where they occur on limestone benches in the high splash zone with *C. exarata*. Fossil shells which may represent the species have been found on Oahu and Maui.

Cellana sandwicensis (Pease, 1861b). Fig. 12 D-F. (Synonyms: *Helcioniscus exaratus* Nuttall, Dall, 1871, in part; *Patella sandwichensis* Tinker, 1958; *C. exarata* Powell, 1973, in part.) Length, 42 mm; diameter, 32 mm; height, 16 mm. *Shell:* conical, slightly broader posteriorly; apex subcentral. *Sculpture:* strong, subcarinate, radiating ribs extending beyond margin of shell giving it a scalloped appearance. *Color:* gray with black ribs; internally iridescent white; spatula black or white, often considerably raised in older specimens. Juvenile shells up to about 15 mm in length are white speckled with black. *Animal:* foot yellow; mantle yellow-gray, with long, thin, extrapallial tentacular processes up to 20 mm in length.

These opihi are found on basalt substrates at and below the zero tide mark, usually on coralline algae where there is almost constant splash. The shells often bear tufts of algae such as *Ulva* and *Pterocladia*, reflecting their habit on the low shore. Associated with *C. sandwicensis* are the helmet urchin, *Colobocentrotus atratus*, and the carnivorous gastropods *Morula granulata, Drupa morum, Purpura aperta*, and *Thais intermedia*. *Purpura* and *Thais* feed on the opihi, but predation does not appear to be common. The home scars consist of oval impressions in the coralline algal substrate, but, as in *C. exarata*, the basalt is not eroded away as it may be by patellids elsewhere.

The sexes are separate and fertilization is external. Settlement occurs when the opihi are about 1 mm in length. Average growth rates for opihi on Hawaii are about 5 mm per month, and the opihi are mature when the shells are about 25 mm in length. As in *C. exarata*, spawning occurs primarily in December and January and recruitment is most noticeable from March to May.

These opihi are common along the basalt shores of all the windward islands, and have also been found at Necker and Nihoa, but they have not been recorded north of these islands.

Cellana talcosa (Gould, 1846). Fig. 12 I, J. (Synonyms: *Helcioniscus argentatus* Sowerby, Edmondson, 1933; *Patella argentata* Sowerby, Pilsbry, 1891, non *P. argentata* Bosc, 1801; *P. cuprea* Reeve, 1854.) Length, 90 mm; diameter, 78 mm; height, 23 mm. *Shell:* domelike, inflated; apex near anterior third. *Sculpture:* fine radiating ribs that do not extend beyond the margin. *Color:* externally brown but usually covered with a growth of seaweed and/or barnacles, or a lime deposit; ribs brown; interior coppery; spatula white, often raised in older specimens.

These limpets are usually found below the low tide mark, at depths of 1 to 10 m; juveniles are occasionally found higher along the shoreline on coralline algae. This is the largest species of Hawaiian limpet, specimens reaching a length of 120 mm and a diameter of more than 90 mm. Pearls have been reported in these limpets on at least two occasions (Kay, 1967c).

Specimens of *C. talcosa* are common on Maui, Molokai, Lanai and Hawaii, but are not recorded from Oahu or the Northwest Islands and they are rare on Kauai.

Superfamily TROCHACEA

This superfamily includes top and turban shells (Trochidae and Turbinidae), the pheasant shells (Phasianellidae), and ear shells (Stomatellidae), all of which are distinguished by their entire apertures and nacreous inner shell layer.

These gastropods differ from the fissurellids and the patellids in that the characteristic paired structures in the mantle cavity of the archaeogastropods are modified, and the animals may have but a single kidney and gill. The foot is surrounded by epipodial outgrowths, slender tentacular projections that often extend beyond the edge of the operculum; these are presumably tactile sense organs.

Family **Trochidae**

The Trochidae, or top shells, comprise a large family which is extensively distributed in both tropical and temperate regions, and from shallow waters to great depths of the sea. Their shells are conical or turbinate. The brilliant internal nacreous layer in some forms, such as *Trochus niloticus* Linn. 1758 and *T. maculatus* Linn. 1758 of the Indian Ocean and central Pacific, has been exploited for commercial purposes, especially the manufacture of pearl buttons. The members of the family are distinguished from the conchologically similar Turbinidae by the type of operculum: in the trochids it is thin and horny; in the turbinids thick and calcareous.

Trochids do not adhere strongly to the substrate and are usually found in fairly protected habitats. Except for *Trochus intextus*, the shallow-water Hawaiian trochids are small-shelled forms (4 to 5 mm in height); they are common in tide pools, and on benches and reefs.

KEY TO SPECIES OF SHALLOW-WATER TROCHIDAE FOUND IN HAWAII

1. Surface smooth or finely spirally striate 2
   Surface with beaded spiral cords 4
2. Columella with a single tooth 3
   Columella not toothed ..... *Gibbula marmorea*
3. Shell elongate-conic; surface smooth ..... *Thalotia ocellata*
   Shell short, angulated; surface spirally striate ..... *Thalotia subangulata*
4. Last whorl without varix 5
   Last whorl with varix behind outer lip ..... *Danilia eucheliformis*
5. Trochiform; periphery angulate; base flat 6
   Turbiniform; periphery rounded; base convex ..... *Euchelus gemmatus*
6. Of moderate size (10 mm); beading of irregularly sized, closely spaced nodules ..... *Trochus intextus*
   Small (4 mm); beading of prominent, well-spaced nodules ..... *Euchelus corrugatus*

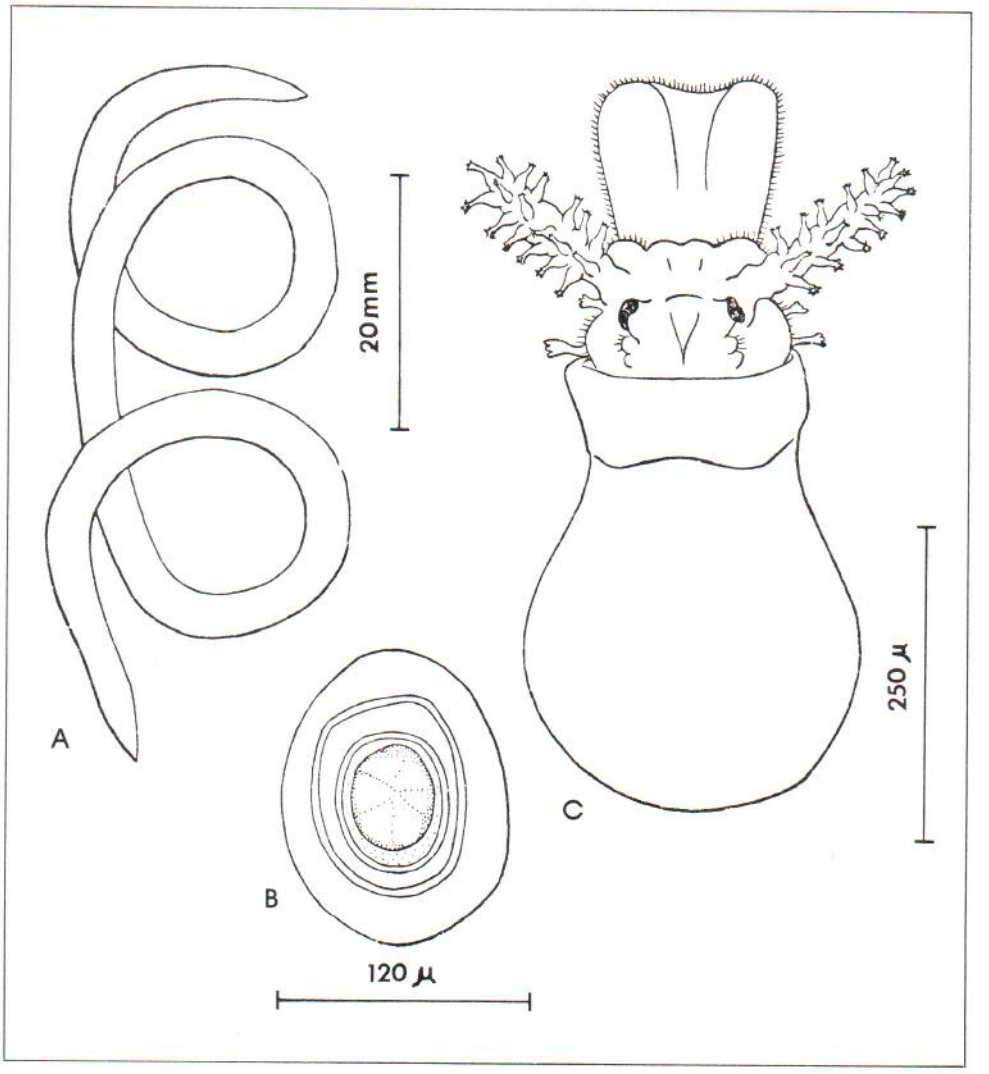


Figure 13.—*Euchelus gemmatus*. A. Egg mass. B. Egg. C. Dorsal view of late veliger stage. (After Duch, 1969.)

Calliostoma (Tristichotrochus) doncorni Kay, new species. Fig. 14 J. Length, 19 mm; maximum diameter, 18 mm. *Shell:* trochiform, apex acute; with beaded spiral cords; yellow-white. *Spire:* protoconch of one and one-half smooth whorls; teleoconch of six slightly convex whorls; suture barely constricted. *Sculpture:* spiral sculpture predominant, of about six cords on the penultimate whorl, three near the periphery noticeably prominent, interspaces wider than the cords and with an intercalary thread, cords and threads finely beaded; base with similar sculpture of about 12 cords between the rounded margin and the umbilical depression. *Aperture:* subquadrate, outer lip thin, simple; columella short; umbilical depression small. *Color:* yellow-white.

These trochids have been dredged at depths of 250 to 280 m. *Type locality:* in a precious coral bed at a depth of 250 m off Makapuu, Oahu. *Holotype:* Bernice P. Bishop Museum No. 9742.

The shells of *C. doncorni* may be distinguished from those of three species of *Calliostoma (Tristichotrochus)* from Japan: The shells of *C. tosaensis* (Kuroda and Habe, in Habe 1961a) are larger (28 mm in height), have overhanging whorls and the spiral sculpture is "distinctly prickly"; those of *C. aculeatus* Sowerby (in Kira, 1962) have spiny tubercles and those of *C. kiiensis* Ikebe (in Kira, 1962) have an angled base. The shells of a fossil species, *C. (T.) hahaensis* (MacNeil, 1960) from the Ryukyu Islands have a less attenuate and more convex spire but the spiral sculpture is similar. This species is named for Mr. Don Corn who first recognized the shells as distinctive.

Danilia eucheliformis (Nomura and Hatai, 1940). Fig. 14 C, D. (Synonym: *Euchelus midwayensis* Habe and Kosuge, 1970.) Length, 10 mm; diameter, 8 mm. *Shell:* turbiniform; with spiral keels and axial lamellae; outer lip with a prominent varix; dirty white with brown, flamelike markings. *Spire:* five convex whorls plus protoconch; suture deep. *Sculpture:* nodular spiral keels separated by interspaces greater in diameter than the keels; keels joined axially by lamellae which override the keels on the apical whorls but which are restricted to the interspaces between keels on the abapical whorls; a prominent, oblique varix extending across the last whorl behind the outer lip. *Aperture:* subcircular, lirate within; outer lip barely thickened; columella irregularly denticulate ending with a prominant tooth at base; base convex, umbilicate, sculpture as on spire. *Color:* dirty white to gray with brown, flamelike markings.

This is a commonly occurring trochid at depths of from 15 to 200 m. The record of this species from Midway (as *Euchelus midwayensis* Habe and Kosuge, 1970) indicates that it occurs throughout the Hawaiian chain.

Monodonta eucheliformis was described from Kyuroko-Sima, Japan. Beu and Climo (1974) refer the Nomura and Hatai species to *Danilia*, a genus now including only seven Recent species, all apparently found at depths of several hundred meters.

Euchelus corrugatus Pease, 1861b. Fig. 14 A. (Synonym: *Euchelus gemmatus* Gould, Edmondson, 1933.) Length, 4 mm; diameter, 4 mm. *Shell:* trochiform; with granular spirals; cream with flashes of dark red. *Spire:* five whorls; suture grooved. *Sculpture:* granular keels separated by interspaces equal in diameter to the keels, and axially joined by obliquely set lamellae of lesser diameter. *Aperture:* subcircular; iridescent and lirate within; outer lip thick; columella straight, toothed at the base; base convex, umbilicus of variable depth; base with obsolete spiral granules; operculum circular, horny, multispiral with a central nucleus. *Color:* white or cream with flamelike markings of ashy rose. *Animal:* exposed parts yellow except for the cephalic tentacles, which are outlined in black.

E. corrugatus is a commonly occurring trochid in the leeward islands and on Kauai, but is rare along the shorelines of Oahu, Maui, and Hawaii. On Kauai it is found on rocks and rubble in tide pools and on benches.

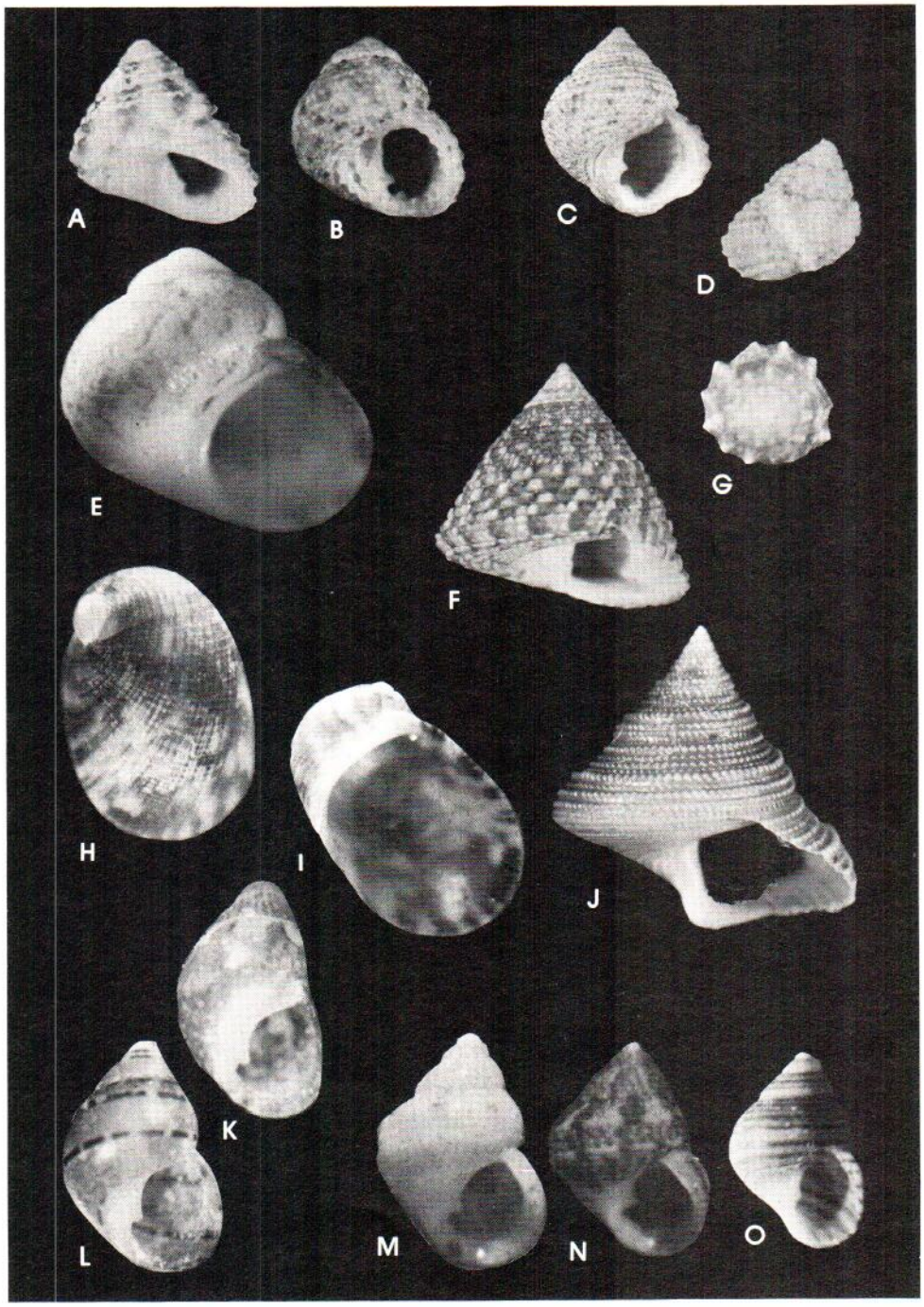


Figure 14.—**Trochidae** and **Stomatellidae.** A. *Euchelus corrugatus*, length 4 mm. B. *E. gemmatus*, length 4 mm. C, D. *Danilia eucheliformis*, length 10 mm. E. *Gibbula marmorea*, length 4 mm. F. *Trochus intextus*, length 25 mm. G. *T. intextus*, dorsal view of juvenile shell, diameter 5 mm. H, I. *Synaptocochlea concinna*, length 3 mm. J. *Calliostoma doncorni*, length 20 mm. K, L. *Thalotia ocellata*, length 3 mm. M, N, O. *T. subangulata*, length 2.5 mm.

This species was described from the Hawaiian Islands and also occurs along the coastline of southern India, and at Bikini in the Marshall Islands.

Euchelus gemmatus (Gould, 1845). Figs. 13, 14 B. Length, 4 mm; diameter, 4 mm. *Shell:* turbiniform; with granular spirals; cream with dark red spots. *Spire:* four convex whorls excluding the protoconch; suture barely distinguishable. *Sculpture:* nodulose spiral keels joined by obliquely set axial lamellae and separated by interspaces equal in diameter to the keels. *Aperture:* subcircular; outer lip thick and lirate within; columella straight, toothed at base; operculum circular, horny, multispiral with a central nucleus; base convex, umbilicate, granular spirals as on spire. *Color:* variable — white or white spotted or streaked with red or black; with a matlike gray periostracum; apex and base white; aperture brilliantly iridescent; operculum tinted black. Beachworn shells cream with flashes of dark red. *Animal:* exposed parts yellow, except the dorsal surface of proboscis and the cephalic and epipodial tentacles, which are black.

E. gemmatus is one of the most frequently occurring of the Hawaiian trochids, found commonly in tide pools and on solution benches, and less frequently on fringing reefs. Shells are occasionally found in sediments to depths of 40 m. These trochids spawn from late December through April, producing threadlike egg strands which are attached to flat surfaces; development is direct, larvae hatching from the egg capsules about two weeks after spawning (Duch, 1969).

This species was described from the Hawaiian Islands, but it ranges through the Indo-West Pacific from the Seychelles and south India to New Caledonia, southern Japan, and the Marshall Islands.

Gibbula marmorea (Pease, 1861b). Fig. 14 E. (Synonyms: *Margarita striatula* Garrett, 1857; *Trochinella perconfusa* Iredale, 1937; *Conotalpia marmorata* Pease, Kosuge, 1969.) Length, 4 mm; diameter, 3.5 mm. *Shell:* turbiniform; smooth; mottled green and white. *Spire:* five and one-half convex whorls; suture impressed. *Sculpture:* microscopic spiral striae and growth lines. *Aperture:* obliquely oval; outer and basal lips thin; parietal region convex, narrowly umbilicate. *Color:* variable — green or gray, with flamelike markings of darker green and splashes of brown or red; apical whorls white; aperture iridescent.

These trochids occur on small algal-covered rocks in tide pools, on benches and on reefs. *G. marmorea* is a common shell on Midway, Kauai, Oahu, Maui, and Molokai but is uncommon along the shorelines of Hawaii. Shells from the leeward islands and Hawaii are conspicuously banded with red, those from Kauai and Oahu are predominantly green.

G. marmorea is apparently widely distributed in the Indo-West Pacific, occurring from Mauritius and the Seychelles to the Marshall Islands (see Ladd, 1966, as *Fossarina hoffmeisteri).* At Noumea, New Caledonia, it was described "in abundance under stones between tidemarks" (Hedley, 1899, as *Gibbula phasianella* Deshayes).

Thalotia ocellata (A. Adams, 1861). Fig. 14 K, L. (Synonyms: *Alcyna rubra* Pease, 1861b; *A. kapiolaniae* Pilsbry, 1917; *A. kuhnsi* Pilsbry, 1917; *A. kuhnsi humerosa* Pilsbry, 1917; *A. rubra multicolor* "Dall," Mant, 1923, *nomen nudum.)* Length, 3 mm; diameter, 1.5 mm. *Shell:* conical, ovate; smooth; with a single tooth on the columella; red or olive. *Spire:* four convex whorls; suture impressed. *Sculpture:* smooth or with microscopic spiral striae. *Aperture:* subcircular; outer lip slightly thickened internally; columellar tooth projecting into aperture; base convex, with a shallow, elongate pseudumbilicus striated by three to five fine grooves. *Color:* variable — live-collected specimens olivaceous or red; beachworn specimens ocellated, lineated, or with flamelike markings of red, pink, or white; apex white.

These mollusks are common but not abundant under encrusting red algae on rocks in tide pools and in shallow water, and have been dredged from depths of 100 m.

T. ocellata was described from Japan and also occurs in the Mariana Islands.

Thalotia subangulata (Pease, 1861b). Fig. 14 M-O. (Synonyms: *Alcyna lineata* Pease, 1869a; *A. striata* Pease, 1869a; *A. subangulata flammulata* Pilsbry, 1917; *A. subangulata virgata* Pilsbry, 1917.) Length, 2.5 mm; diameter, 1.5 mm. *Shell:* turbiniform; whorls angulate and spirally striate; with a single tooth on the columella; deep rose to pale pink. *Spire:* whorls angular; suture impressed. *Sculpture:* fine spiral striae encircling all whorls. *Aperture:* subcircular, outer lip thickened with a swelling externally below the suture; columellar tooth projecting into aperture; base convex, pseudumbilicus triangular, striated by three to five fine grooves. *Color:* variable — deep rose or pale pink spirally striated with darker pink; apex white. *Animal:* foot, head, and epipodial tentacles black.

These trochids are common on fringing reefs but are less frequently found in tide pools and on benches than is *T. rubra*.

T. subangulata was described from the Hawaiian Islands, and also occurs in Mauritius. *Nevillia picta* H. Adams, 1868, is a synonym.

Trochus intextus Kiener, 1850. Fig. 14 F, G. (Synonyms: ?*Trochus ignobilis* Philippi, 1846b; *T. sandwichiensis* Souleyet, 1852.) Length, 25 mm; diameter, 25 mm. *Shell:* trochiform; with granular spiral threads; gray with darker flamelike marks. *Spire:* six to seven convex whorls; suture flush. *Sculpture:* evenly spaced spirals of uniformly-sized beading. *Aperture:* subquadrate; outer lip thin and produced at an angle of 45° from the base; columella thick, with an internal ridge, base toothed; base flat, narrowly umbilicate, encircled by obsoletely granular spirals; operculum thin, horny, polished with a central prominence on the inner side. *Color:* variable — gray or red with spots or flamelike markings of darker tone, the base articulated with red dots on the spirals and with a red smear in the aperture; aperture, columella, and umbilicus iridescent; shells frequently discolored green-gray.

These gastropods commonly occur in shallow, sandy areas studded with rocks, such as in Kaneohe Bay, Oahu. Worn shells are often frequented by hermit crabs. Pleistocene fossils are known from Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939).

T. intextus is apparently limited in its range to the Pacific, occurring from the Philippines and southern Japan to Micronesia and Polynesia.

Additional Records

Specimens of *Clanculus clanguloides* (Wood, 1828) have been recorded from the Hawaiian Islands but are extremely rare. The shell is globose, 12 mm in height, 8 mm in diameter; with finely beaded spirals; red-orange with rose granules. There are no recently authenticated records of two species of *Euchelus* referred to the Hawaiian Islands in the 19th century. *E. fimbriatus* was described from the "Sandwich Islands" by Pease (1861b); the holotype, in the British Museum (Natural History) is a small (3 mm) white shell encircled by sharply pointed granules. *E. maculosus* (Pease, 1863a) was referred to the Hawaiian Islands by Pease; shells which are small (ca. 2 mm in diameter), cream-colored and spotted with red are common in the Marshall Islands.

Several trochids dredged from depths of more than 100 m indicate that there is as diverse a trochid fauna at these depths as is found in shallow water. Shells of *Tristichotrochus margaritissimus* Habe and Okutani, 1968, were dredged at depths of 460 m off Midway. These trochids are 17 mm in height, 15 mm in diameter, turbinate, pale rosy to brownish white and bear three strong, beaded, spiral cords. Three species of *Calliotropis (Solaricida)* have also been described from Hawaiian waters. The turbiniform shells of *C. (S.) reticulina* (Dall, 1895), 7 mm in height, 10 mm in diameter, with spirals of spinous nodules are not uncommon in dredge hauls at depths of 106 to 911 m. *S. (C.) abyssicola* Rehder and Ladd, 1973, and *C. (S.) hataii* Rehder and Ladd, 1973, were described from dredge hauls from guyots of the Mid-Pacific Mountains between the Marshall Islands and Hawaii at depths of 1436 to 2187 m. The former is related to *C. (S.) reticulina* (Dall), the latter to a deep-water species from comparable depths off Japan (Rehder and Ladd, 1973).

Family **Stomatellidae**

The shells of the stomatellids are small, usually low-spired, few-whorled, and ear- or slipper-shaped. The aperture is large, and through it the apical whorls are visible. All known species are littoral and herbivorous.

Synaptocochlea concinna (Gould, 1845). Fig. 14 H, I. (Synonym: *Synaptocochlea concinna inconcinna* Pilsbry, 1921.) Length, 3 mm; diameter, 2 mm. *Shell:* flat, ear-shaped; obliquely oval with a few rapidly increasing whorls, the last comprising the greater portion of the shell. *Sculpture:* microscopic spiral threads crossed by finely beaded axial riblets. *Operculum:* small, thin, horny. *Color:* variable — red or pink, mottled with darker shades; aperture iridescent within.

S. concinna occurs with *Thalotia ocellata* and *Leptothyra rubrilineata* under encrusting red algae on rocks in the shallow waters of fringing reefs; living animals are infrequently encountered because of their small size and cryptic coloration but beachworn shells are abundant in drift.

S. concinna was described from the Hawaiian Islands but is widespread in the Indo-West Pacific and may be circumtropical; Abbott (1958) suggests that the Indo-West Pacific species should be considered a subspecies of the western Atlantic *S. picta* Orbigny, 1842, since there appears to be little difference between the two.

Pilsbry's (1921) proposal that a green and white shell be distinguished as *S. concinna inconcinna* is not justified because it was based merely on a color variant and cannot represent a subspecies as the term is now utilized.

Additional Record

The reports of *S. nigra* Quoy and Gaimard 1834 from the Hawaiian Islands by Sowerby (1854) and R. B. Watson (1886) are apparently erroneous.

Family **Skeneidae**

This family includes small to minute trochacean gastropods with circular apertures, nonnacreous interiors, and an umbilicus or umbilical chink. The operculum is chitinous and multispiral and the radula is rhipidoglossate. Long considered a dumping ground for many minute white shells (Abbott, 1974), the family has been clarified by McLean (1969) and Keen (1971), to include genera such as *Haplocochlias* Carpenter, 1864, *Parviturbo* Pilsbry and McGinty, 1945, and *Ganesa* Jeffreys, 1883 from the eastern Pacific. In Hawaiian waters, two genera, *Brookula* Iredale, 1912, with minute, inflated, axially ribbed shells and *Cyclostremiscus* Pilsbry and Olsson, 1945, with discoid, umbilicate shells are represented, and a third genus, *Lophocochlias* Pilsbry, 1921, tentatively located in the family.

Brookula iki Kay, new species. Fig. 15 H-J. Length, 0.75 mm; diameter, 0.5 mm. *Shell:* elevated-turbinate; umbilicate; with axial ribs and spiral threads; white. *Spire:* protoconch of one and one-half smooth whorls; teleoconch of three inflated whorls; suture constricted. *Sculpture:* fine, crisp axial ribs, about 25 on the last whorl, extending into umbilicus; interspaces between ribs about four times the width of the ribs and with fine, sharp spiral threads. *Aperture:* subcircular; peristome continuous; columella arcuate; umbilicus chinklike, deep, slightly encroached upon by the columella. *Color:* white.

Type locality: Mamala Bay, Oahu, from a depth of 400 m. *Holotype:* Bernice P. Bishop Museum No. 9744. Paratypes: Australian Museum, British Museum (Natural History), United States National Museum.

The Hawaiian shells are similar in shape to those of the New Zealand fossils *B. corulum* (Hutton, 1884) and *B. tenuilirata* Finlay, 1924 (see Finlay, 1927), but the continuous axial ribs distinguish the Hawaiian shells from those of *B. corulum* in which the axials are prominent only above the periphery, and the small size of the shells of *B. iki* distinguish them from those of *B. tenuilirata* which are 2 mm in length. Derivation of name: *iki,* Hawaiian — small. Refers to the small size of the shells compared with those of other *Brookula.*

Cyclostremiscus emeryi (Ladd, 1966). Fig. E-G. Height, 0.5 mm; diameter, 1.0 mm. *Shell:* discoid; with beaded spiral carina; white. *Spire:* flat, apex sunken; protoconch of a single smooth whorl; teleoconch of two whorls. *Sculpture:* about nine spiral carina, two at the periphery larger than the others; all spiral carinae except the peripheral pair conspicuously beaded. *Aperture:* subcircular, peristome continuous; outer lip thin, slightly angled by the carinae; umbilicus wide and deep. *Color:* white.

These minute shells are common in tide pools and on fringing reefs and are found in sediments to depths of 50 m.

C. emeryi was described from Miocene sediments at Enewetak, Marshall Islands, and Recent shells are recorded from Rongerik and Bikini (Ladd, 1966).

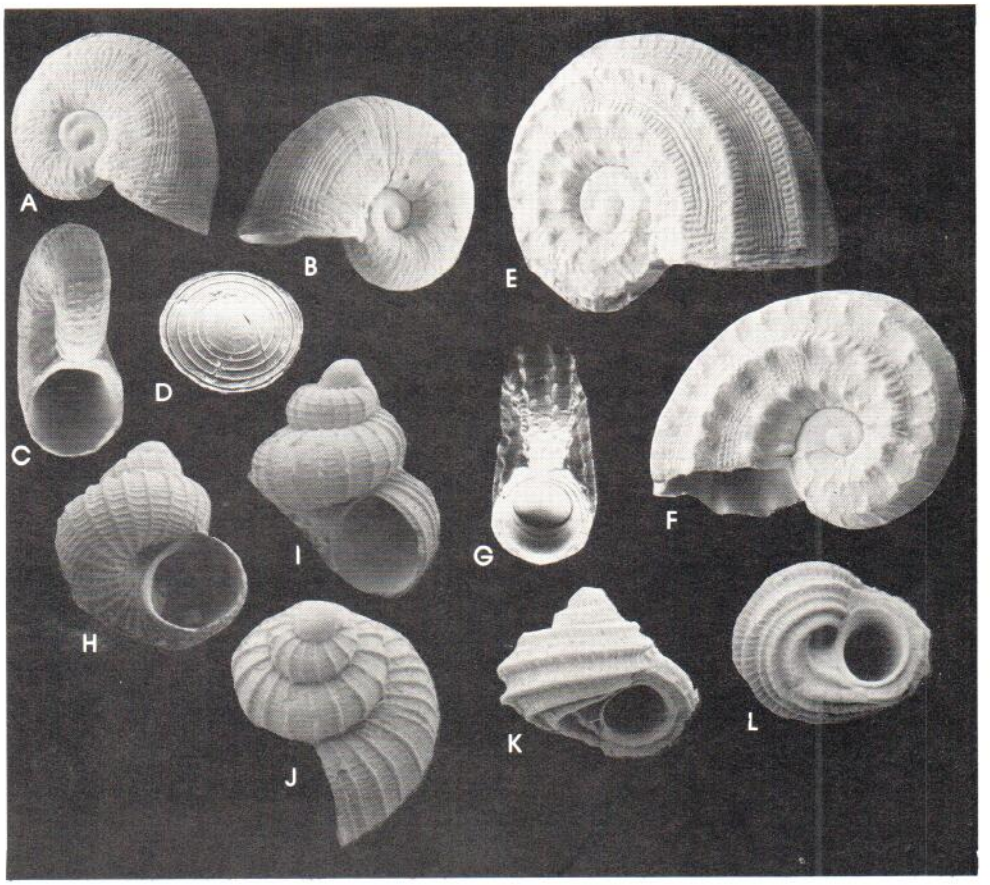


Figure 15.—**Skeneidae.** A, B, C, D. *Cyclostremiscus striatus*, diameter 1.0 mm. A, B. Top and bottom views of shell; C, apertural view; D, operculum. E, F, G. *C. emeryi*, diameter 1.0 mm. H, I, J. *Brookula iki*, length 0.75 mm, holotype. K, L. *Lophocochlias minutissimus*, length 1 mm.

Cyclostremiscus striatus Kay, new species. Fig. 15 A-D. Height, 0.5 mm; diameter, 1.0 mm. *Shell:* discoid; with microscopic axial and spiral striae; white. *Spire:* flat, apex sunken; protoconch of one and one-half smooth whorls; teleoconch of one whorl, periphery rounded; suture deeply impressed. *Sculpture:* periphery of last whorl with a single carina; upper surface of whorl with axial striae parallel to the carina and radial striae crossing the axials on about two-thirds of the whorl; lower surface with spiral striae only. *Aperture:* circular, peristome continuous; umbilicus wide and deep. *Operculum:* circular, paucispiral. *Color:* white.

These minute prosobranchs are common in seaweed in tide pools and are occasionally found in sediments to depths of 30 m.

Type locality: Honaunau Bay, Hawaii. *Holotype:* Bernice P. Bishop Museum No. 9747. *Paratypes:* Australian Museum; British Museum (Natural History); United States National Museum.

The shells are distinguished from those of *C. emeryi* by the lack of beaded carina. They are similar in outline to those of *C. pachynepion* Pilsbry and Olsson, 1945, from

Colombia but lack the bold carina. Derivation of name: *stria,* Latin — a channel. Refers to the spiral sculpture on the shells.

Lophocochlias minutissimus (Pilsbry, 1921). Fig. 15 K, L. Length, 1 mm; diameter, 1 mm. *Shell:* turbiniform; spirally keeled and with fine axial threads; white. *Spire:* protoconch of two and one-half acute, brown whorls, the apical smooth, the others with oblique axial ribs; teleoconch of three convex whorls, the last the largest. *Sculpture:* apical whorl with granular axial ribs and spiral threads, the next with two and the last with six spiral keels; interspaces between the spiral keels of greater diameter than the keels, shallow, crossed by numerous axial threads. *Aperture:* subcircular, oblique; outer lip with an external varix; umbilicus wide and deep; operculum circular, multispiral, horny. *Color:* white.

These gastropods are found around the bases of seaweeds in tide pools and on solution benches and are common in sediments to depths of 30 m.

L. minutissimus was described from the Hawaiian Islands but is widely distributed in both space and time: Recent shells are reported from the Tuamotu and Marshall Islands, Miocene fossils from the Marshall Islands and Fiji, and a Pleistocene fossil from Tonga (Ladd, 1966). The shells of *Liotia parvissima* Hedley, 1899, from Funafuti are distinguished by their more prominent spiral keels and different protoconch. This species is only tentatively included in the Skeneidae. The veliger larvae exhibit both rissoacean and cerithiacean features, resembling rissoids with respect to the inflated shell and cerithids with respect to sculpture and rounded aperture (J. B. Taylor, 1975).

Family **Turbinidae**

The turban shells comprise a large family of few-whorled globose shells which range in height from more than 50 mm to less than 1 mm. All members of the family have a characteristic solid, calcareous operculum, often sculptured and colored externally, and with a heavy brown periostracum internally. Herbivores, most turbinids live in the shallow waters of the littoral zone of the tropics and subtropics.

KEY TO THE SPECIES OF HAWAIIAN TURBINIDS

1. Adult shell to 5 mm in height;
   operculum smooth, white 2
   Adult shell more than 10 mm height;
   operculum granular, colored ..... *Turbo sandwicensis*
2. Shell tessellated or lineated with
   red or brown 3
   Shell white or cream, often tinted
   with pink on apex ..... *Leptothyra candida*
3. Shell minute (1-2 mm), spirally
   lineated with red and white ..... *L. rubricincta*
   Shell 3-5 mm, maculated or
   tessellated with brown or red ..... *L. verruca*

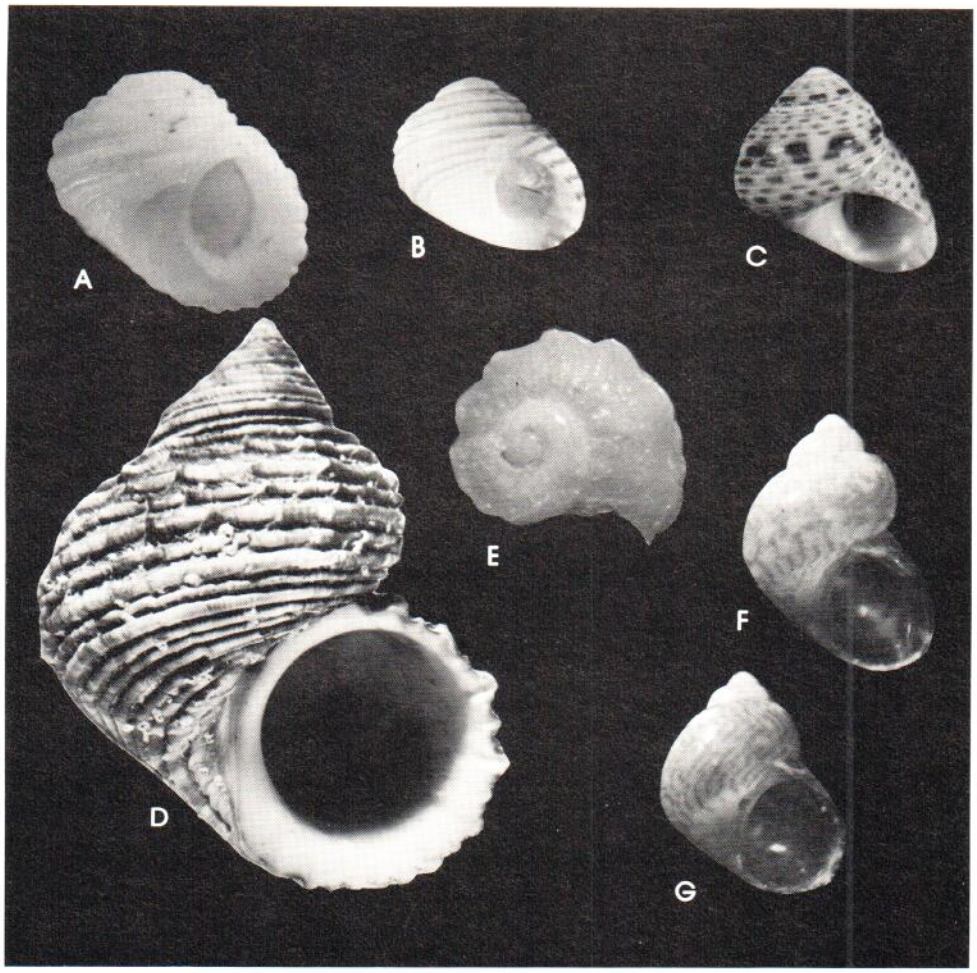


Figure 16.—A. *Leptothyra candida*, length 4 mm. B. *L. rubricincta*, length 2 mm. C. *L. verruca*, length 5 mm. D. *Turbo sandwicensis*, length 50 mm. E. *T. sandwicensis* juvenile shell, 2 mm. F. *Tricolia variabilis*, female shell, length 3 mm. G. *T. variabilis*, male shell, length 3 mm.

Leptothyra candida (Pease, 1861b). Fig. 16 A. Length, 4 mm; diameter, 4 mm. *Shell:* turbiniform, solid; encircled by strong spiral keels; white. *Spire:* four convex whorls separated by a deep suture. *Sculpture:* convex, spiral keels of varying size encircling whorls and base; apex granular. *Aperture:* circular; outer lip thickened; base with a crenulate granular ridge bordering the umbilicus; operculum multispiral, white. *Color:* cream or white with faint pink maculations on the apical whorls.

This is the least common of the Hawaiian species of *Leptothyra*, found mainly in tide pools and on fringing reefs.

L. candida was described from the Hawaiian Islands and has been reported from the Seychelles (J. D. Taylor, 1968), and shells resembling those from the Hawaiian Islands are reported as Miocene fossils from Enewetak, Marshall Islands (Ladd, 1966).

Leptothyra rubricincta (Mighels, 1845). Fig. 16 B. (Synonyms: *Turbo multilineata* Garrett, 1857; *Collonia rubrilineata* "Pease," Sowerby, 1886; *C. multistriata* "Pease," Sowerby, 1886.) Length, 2 mm; diameter, 2 mm. *Shell:* turbiniform, compressed; solid; with spiral keels; spirally threaded with red and white. *Spire:* four convex whorls; suture indistinct. *Sculpture:* smooth spiral keels and interspaces of equal diameter. *Aperture:* subcircular; outer lip thick; columella straight; base umbilicate; operculum multispiral, white. *Color:* spiral keels pink or red, interspaces white, or vice versa; apex and base white.

These mollusks are common under encrusting red algae on rocks and rubble in tide pools and on fringing reefs. Shells are found occasionally in sediments to depths of 60 m.

L. rubricincta was described from the Hawaiian Islands and occurs throughout the Indo-West Pacific. Shells resembling this species are also found at St. Helena in the Atlantic Ocean.

Leptothyra verruca (Gould, 1845). Fig. 16 C. (Synonyms: *Collonia costata* Pease, 1869b; *Leptothyra verruca manti* Pilsbry, 1921; *L. balnearii* Pilsbry, 1921; *L. viaria* Pilsbry, 1921.) Length, 5 mm; diameter, 5 mm. *Shell:* turbiniform; with faint spiral keels; maculated brown or red and white. *Spire:* five convex whorls, the last the largest and forming three-quarters of the spire; suture indistinct. *Sculpture:* spiral keels of varying size with threadlike striae in the interspaces. *Aperture:* circular; outer lip thick and smooth; columella arcuate and wide, with a small, internal denticle; base short with a narrow umbilicus or without umbilicus; operculum thick, multispiral, white. *Color:* variable — white with spiral bands of red and brown tessellations; entirely brown or red.

These turbinids are abundant on and under rocks and rubble, in tide pools and on solution benches and fringing reefs. Shells are occasionally found in sediments to depths of 20 m.

The species described by Pease (1869b) and Pilsbry (1921) fall well within the color and sculptural variations exhibited by *L. verruca*. In juvenile shells the columella is narrow apically and flares basally, producing the excavated effect which Pilsbry (1921) used to distinguish *L. viaria*. *L. verruca manti* Pilsbry (1921) represents a color variant and not a subspecies as this taxon is now defined.

L. verruca was described from the Hawaiian Islands and is of restricted Indo-West Pacific distribution: shells from western Australia are indistinguishable from Hawaiian specimens and shells from Miocene drill holes at Enewetak, Marshall Islands, have been reported by Ladd (1966) as *L. balnearii*.

Turbo sandwicensis Pease, 1861b. Fig. 16 D, E. (Synonyms: *Turbo semicostatus* Pease, 1861b non *T. semicostatus* Montagu, 1803; *T. intercostalis* Menke, 1846, Pilsbry, 1888; *Marmorostoma intercostalium* (Menke), Kosuge, 1969.) Length, 50 mm; diameter, 40 mm. *Shell:* turbiniform, solid; with granular or scaly spiral sculpture; green with brown and black. *Spire:* five whorls plus the protoconch, last whorl the largest and rapidly enlarging beyond the apical whorls; suture impressed. *Sculpture:* spiral grooves and ridges, the former often with axial lamellae, the latter sometimes bearing scalelike processes. *Aperture:* circular, outer lip thick; columella straight; base umbilicate; operculum calcareous, granular, marked externally by green

and brown. *Color:* variable — green or gray with irregular flashes of green, black, and brown; interior silvery.

These mollusks are common under rocks in shallow waters shoreward of fringing reefs and on the outer edges of reefs; worn shells were dredged by the *Albatross* at depths of 56 to 86 m. Pleistocene fossils are known from Oahu and Molokai (Ostergaard, 1928, 1939, as *T. intercostalis).*

T. sandwicensis was described from the Hawaiian Islands. Although the Hawaiian shells resemble *T. argyrostomus* Linnaeus, 1758, which is widely distributed in the Indo-West Pacific, certain features are consistently distinctive: only occasional shells exhibit spiral scales and when scales are present they are always less developed than they are in shells from elsewhere in the Pacific, and the operculum lacks both the conspicuous axial threads and golden marginal band characteristic of the periphery of operculae in shells from other areas. Within the Hawaiian chain, *T. sandwicensis* displays marked variability: shells from the leeward islands are of massive size (some more than 90 mm in length), the whorls may be disjunct, and scales are more frequently present than they are on shells from the windward islands. The shells with disjunct whorls have been recorded as *T. articulatus* Reeve, from Kure (Rehder and Ladd, 1973).

Additional Records

Turbo setosus Gmelin, 1791, is reported from Pleistocene fossil deposits by Ostergaard (1928), but does not now live in Hawaiian waters.

Galeoastrea midwayensis Habe and Kosuge, 1970, was described from specimens dredged off Midway. The shells are turbinate, solid, nacreous, 29 mm in height, 31 mm in diameter. They are light brown-red to yellow-brown, with irregularly arranged, white, flamelike markings and sculptured with three spirals of beaded granules with interstitial rows between. The operculum is thick, calcareous, glossy and smooth on the convex outer surface.

Family **Phasianellidae**

The pheasant shells are conic-ovate and few-whorled with a smooth or finely striate, porcelaneous surface. The operculum is turbinid, with an eccentric nucleus.

Tricolia (Hiloa) variabilis (Pease, 1861b). Figs. 7 B; 16 F-G; 17. (Synonyms: *Phasianella ambigua* "Nuttall" Jay, 1839, *nomen nudum; P. molokaiensis* Pilsbry, 1918; *P. variabilis kahoolawensis* Pilsbry, 1918; *P. thaanumi* Pilsbry, 1918; *P. bryani* Pilsbry, 1918.) Length, 3 mm; diameter, 1.5 mm. *Shell:* conic-ovate; thin; smooth; variegated pink and white. *Spire:* four convex whorls separated by an impressed suture. *Aperture:* subcircular; outer lip reflexed; base deeply but narrowly umbilicate; operculum convex, thick, white. *Color:* variable — white, mottled, banded, or with flamelike markings, pink, red, or olivaceous.

These are among the most abundant and ubiquitous of all gastropods found in Hawaiian waters, occurring from the intertidal to depths of 100 m. In tide pools and on fringing reefs *T. variabilis* is especially associated with the brown alga, *Padina,* on

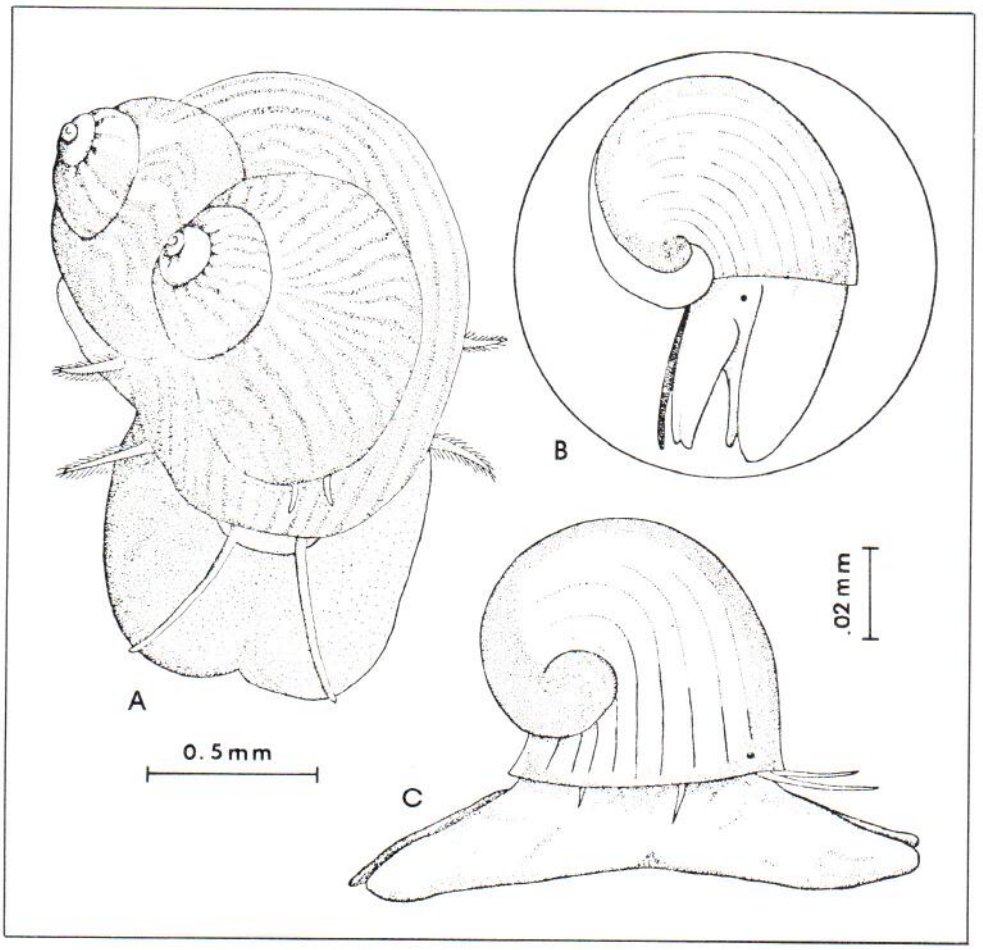


Figure 17.—*Tricolia variabilis*. A. Smaller male on larger female in breeding position. B. Forty-eight-hour veliger. C. Sixteen-day-old juvenile. (After Wertzberger, 1968.)

which the animals feed and spawn (Wertzberger, 1968). During the spawning season, from October to January, they are often found in pairs, the females carrying the males on the shoulder of the last whorl (Fig. 17 A). Both the shells and the radula are sexually dimorphic (Robertson, 1971). Male shells are smaller than female shells and, unlike females, have flared outer lips. A pelagic larval stage is suppressed and development is direct, juveniles emerging from the egg capsules about 16 days after oviposition (Wertzberger, 1968). Juveniles are frequently found in the plankton; they produce mucous nets by means of which they can traverse the water column (J. B. Taylor, 1975). *T. variabilis* is the second most common food species of the mollusc-ivorous cone, *Conus pennaceus* (Kohn, 1959a).

This species was described from the Hawaiian Islands but is widespread in the Indo-West Pacific, distributed from the east coast of Africa through the Indian Ocean, and in the Pacific north to Honshu, Japan, and south to New South Wales and the

Cook Islands. It is reported from Recent to upper Miocene drill holes at Bikini, Marshall Islands (Ladd, 1966).

T. variabilis resembles the trochid *Thalotia ocellata* in size, shape, and color, but is distinguished by its calcareous operculum and the absence of a columellar tooth.

Superfamily NERITACEA

The Neritacea include marine, freshwater, and terrestrial mollusks, which are mainly associated with the tropics and subtropics. Most members of the group have ovate shells with few whorls, and the spire, if it projects, is relatively low. The operculum is calcareous, often with processes projecting from the inner face.

As is usual in a group of animals inhabiting a diversity of habitats, the members of the group display an assortment of both primitive and advanced characters. While several features of the archaeogastropods, such as paired auricles, are recognizable, other characters are present that can be associated with the intertidal conditions under which some of the neritaceans live and with the invasion of freshwater and land by others: the modification of the gill and the use of the body wall as an accessory respiratory structure; the loss of the right kidney; and the development of a complex genital apparatus. This last feature makes possible internal fertilization and the production of egg capsules (Fretter, 1965).

Family **Neritopsidae**

This family includes a number of genera, but, except for *Neritopsis*, all are fossil forms. The shell in *Neritopsis* is globular, the spire protrudes only slightly, the last whorl is large, the inner lip is broad and smooth and there is a calcareous operculum.

Neritopsis radula (Linnaeus, 1758). Fig. 19 A, B. Length, 16 mm; diameter, 15 mm. *Shell:* globose; spirally corded; white. *Spire:* low, last whorl much the largest; suture obscure. *Sculpture:* finely granular spiral cords which encircle all the whorls. *Aperture:* subcircular; outer lip jutting out; parietal callus covering a part of the base of the last whorl; columella with a single tooth at the base. *Color:* white.

This is a rare deep-water species in the Hawaiian Islands: three or four specimens have been dredged at depths of 200 m, and a fossil shell was recorded in a dredge haul from a drowned Miocene terrace off Oahu (Allison, pers. comm.).

N. radula is widely distributed in the Indo-West Pacific; in the Pacific it has been recorded from Kyushu and southern Japan (Kira, 1962), and it is common in beach drift at Kwajalein, Marshall Islands, and at Fanning Island in the Line Islands (Kay, 1971).

Family **Neritidae**

The nerites are among the most widespread and abundant of molluscan families, inhabiting tropical and subtropical shorelines from the splash zone to a meter below the zero tide mark, and streams and rivers far from the sea. The shells are globose,

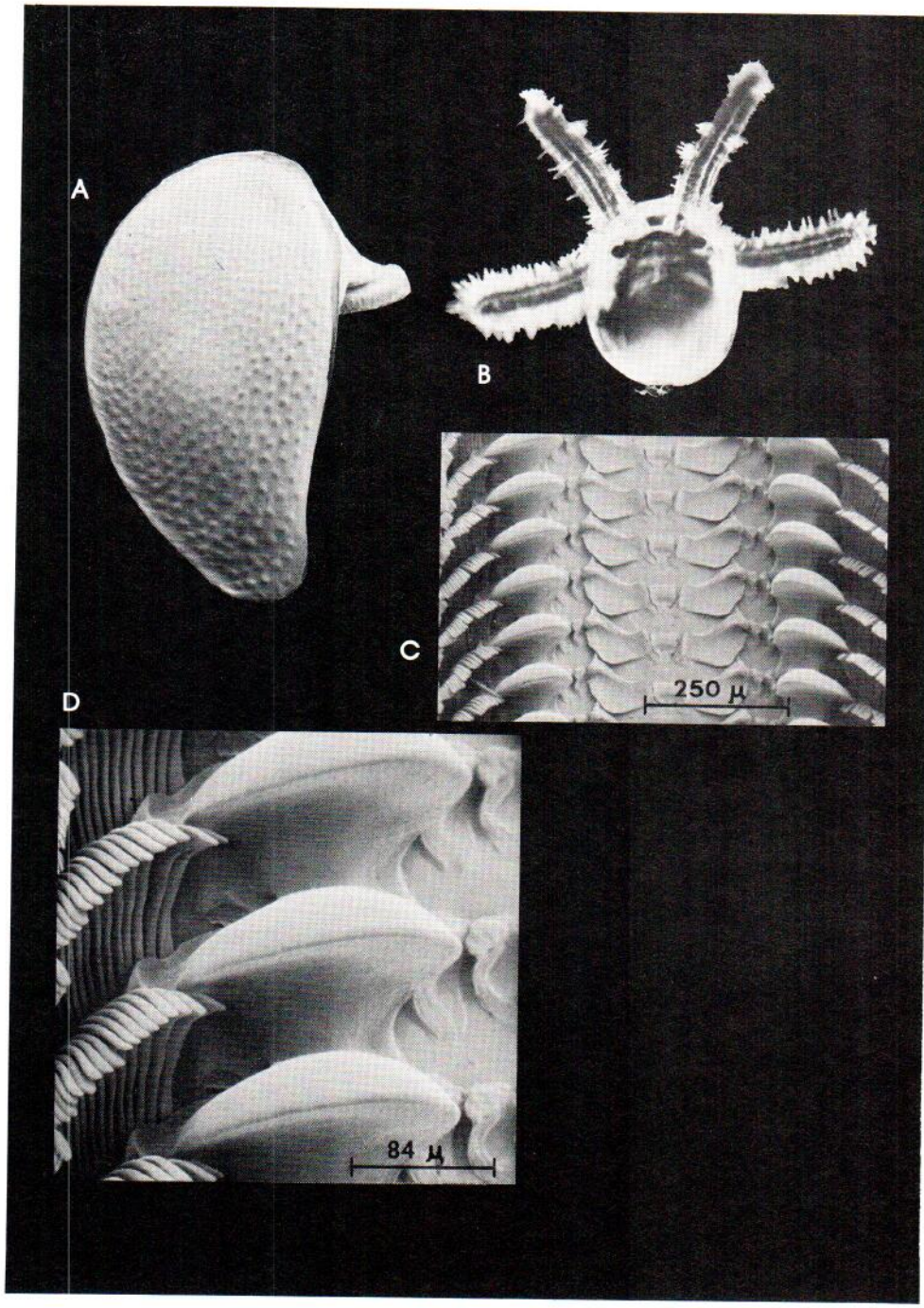


Figure 18.—*Nerita picea*. A. Operculum. B. Veliger larva. C, D. Radula. (B by J. B. Taylor, 1975.)

with a characteristic semicircular toothed aperture; the inner lip forms a deck which gives them a limpetlike aspect. There is a tight-fitting, calcareous operculum which bears an internal, clawlike process, the apophysis.

Herbivores, nerites browse on algae covering the rocky substrate on which most of them live. They deposit their eggs in white, oval capsules which are firmly attached to the surface of shells and rocks. The egg capsules are so durable as to sometimes be seen on shells in museum collections. All the Hawaiian nerites have a pelagic veliger larva. The protoconch is globose, the velum quadrilobed, and the cephalic tentacles long and tapering (J. B. Taylor, 1975) (Fig. 18 B). They are active swimmers and appear in the plankton throughout the year with peak settlement in the winter in Hawaii (J. B. Taylor, 1975).

The Hawaiian nerite fauna includes not only typical marine forms but three species which are diadromous, that is, the animals migrate between freshwater and the sea during their life cycles. *Neritina granosa, Theodoxus cariosus,* and *T. vespertinus* live as juveniles and adults in freshwater streams, but their larvae develop in the ocean.

Nerita picea (Recluz, 1841). Figs. 18; 19 J. (Synonym: *Neritina insculpta* Reeve, 1855.) Length, 14 mm; diameter, 11 mm. *Shell:* globose, solid; with incised spiral grooves; black. *Spire:* three whorls; spire fairly prominent but sometimes eroded. *Sculpture:* unequally spaced, fine, spiral grooves. *Aperture:* lunate; outer lip thin with 15 to 20 teeth; inner lip with two to six irregular teeth; septum thick, slightly concave, smooth. *Operculum:* calcareous, red-brown, the surface finely granular. *Color:* black, occasionally vaguely marked with white.

N. picea is the dominant nerite along Hawaiian shorelines, abundant on all rocky substrates from the splash zone to high-water mark just below the littorines. The vertical movements of these nerites with the tide are especially noticeable on limestone shorelines. This species is recorded in Pleistocene deposits on Oahu (Ostergaard, 1928). *N. picea* and *Theodoxus neglectus* were called *pipipi* by the Hawaiians who used the animals for food and the shells for leis.

N. picea was described from the Hawaiian Islands but has also been recorded from various localities in the Pacific (for example, Indonesia by Adam and Leloup, 1938). It seems to be very rare elsewhere in the Pacific, except at Johnston Island, where it is apparently as abundant as it is in Hawaii.

Nerita plicata Linnaeus, 1758. Fig. 19 G. Length, 20 mm; diameter, 19 mm. *Shell:* globose; spirally corded; gray-white. *Spire:* three whorls; spire prominent. *Sculpture:* thick spiral cords separated by grooves of about equal diameter. *Aperture:* lunate; outer lip with ten teeth, inner lip with three or four oblique teeth; septum thick, oblique, wrinkled. *Operculum:* thin, light brown, smooth. *Color:* variable — white to brown, often spotted and streaked with black.

Specimens of *N. plicata* are uncommon along the shores of the windward islands where they are infrequently found high on the shoreline in crevices and pits on limestone benches and on the limbs of kiawe (*Prosopis*) trees overhanging the water, but they are frequently found at Midway and Pearl and Hermes Reef.

This species is widespread in the Indo-West Pacific; it is the dominant nerite on atolls throughout the Central Pacific and has been recorded as far east as Clipperton Island (Demond, 1957).

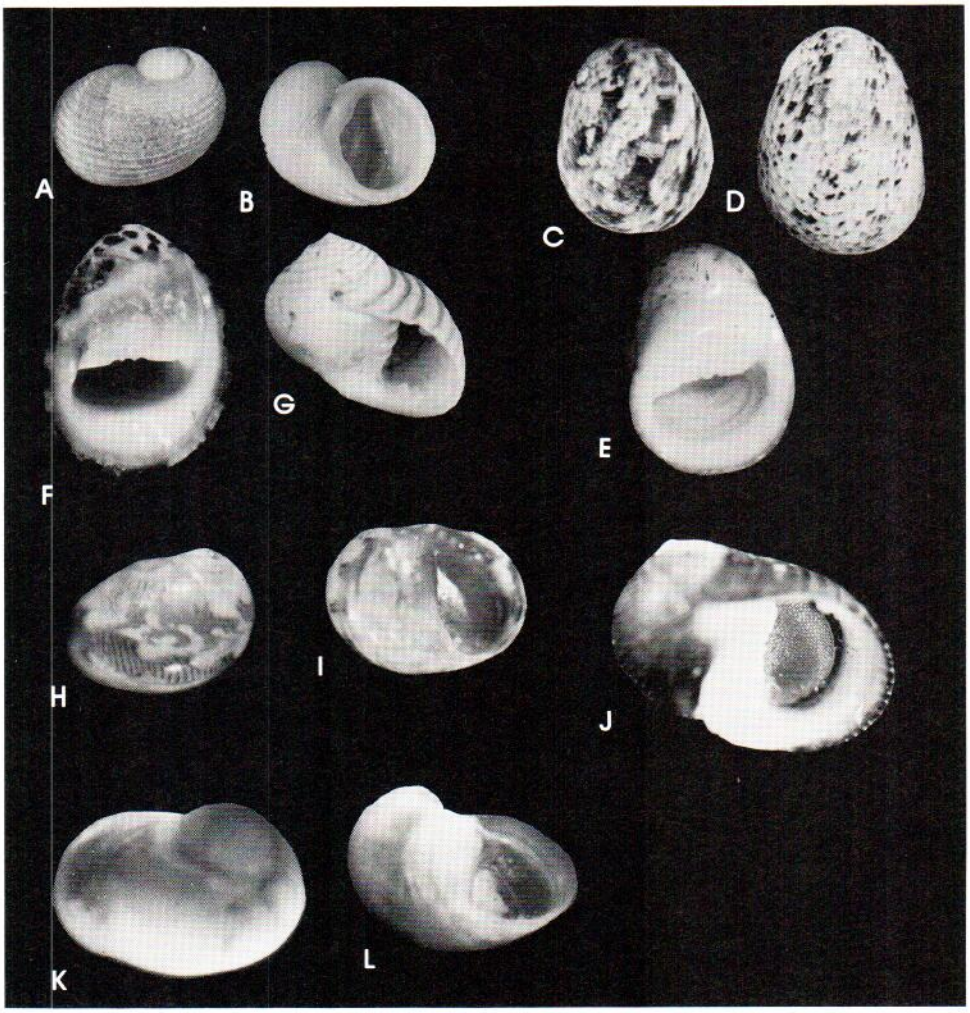


Figure 19.—**Neritopsidae** and **Neritidae.** A, B. *Neritopsis radula*, length 17 mm. C, D, E. *Nerita polita*, length 34 mm. F. *N. albicilla*, length 30 mm. G. *N. plicata*, length 20 mm. H, I. *Smaragdia bryanae*, length 2 mm. J. *Nerita picea*, length 14 mm. K, L. *Neritilia hawaiiensis*, length 2 mm.

Nerita polita Linnaeus, 1758. Fig. 19 C-E. Length, 34 mm; diameter, 22 mm. *Shell:* globose; smooth; mottled gray and white. *Spire:* blunt; three whorls. *Sculpture:* microscopic growth lines. *Aperture:* lunate; outer lip thin and sharp, with numerous fine teeth; inner lip with four or five teeth; septum thick, convex, smooth. *Operculum:* calcareous, surface smooth except for a margin of transverse ridges; apophysis a flat flange; ivory. *Color:* gray or black, variously mottled, banded, or with flamelike markings of darker gray or red.

These mollusks live beneath the surface of the sand among boulders at the high-tide line; seldom seen during the day, the snails emerge at night, plowing through the sand and crawling up the algal covered rocks on which they feed.

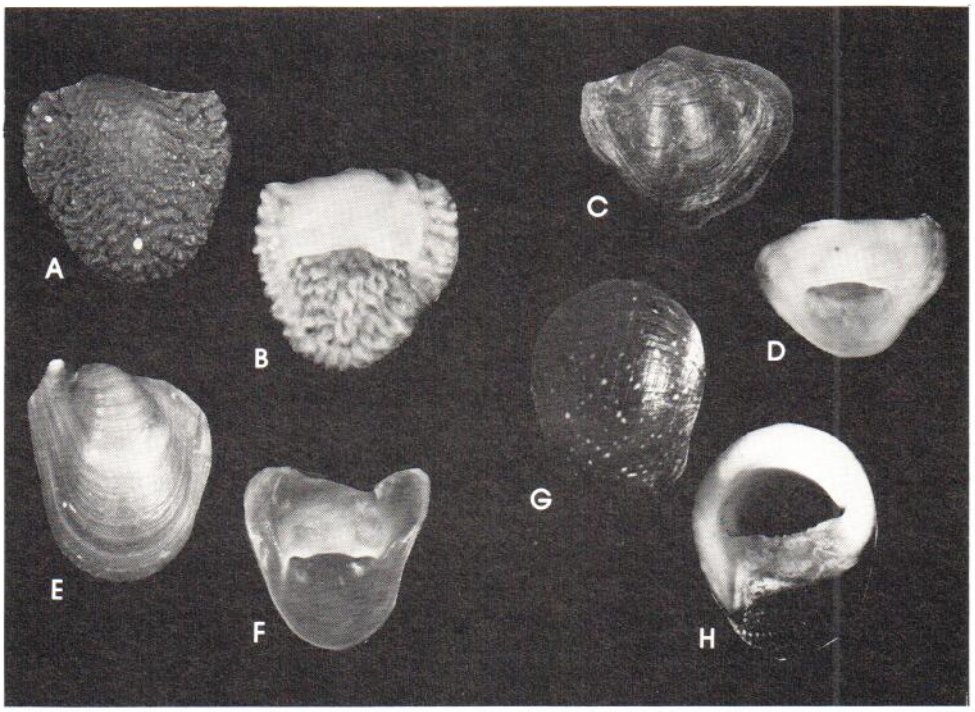


Figure 20.—**Neritidae.** A, B. *Neritina granosa*, length 42 mm. C, D. *Theodoxus cariosus*, length 20 mm. E, F. *T. vespertinus*, length 20 mm. G, H. *T. neglectus*, length 19 mm.

Known as *kūpe'e* by the Hawaiians, shells of *N. polita* were prized as items of adornment and the animals were used as food. Drilled and made into bracelets and necklaces, the *kūpe'e* was an emblem of mourning for the *ali'i*, or chiefs.

N. polita is a well-known species throughout the Indo-West Pacific.

Neritilia hawaiiensis Kay, new species. Fig. 19 K, L. Length, 2.25 mm; diameter, 1.75 mm. *Shell:* obliquely ovate; smooth; yellow-brown. *Spire:* short, depressed, of about three and one-half whorls; suture indistinct. *Sculpture:* microscopic growth striae only. *Aperture:* ovate; outer lip thin; columellar callus extensive; inner lip edentulous. *Color:* yellow-brown.

These nerites are found in low salinity tide pools on Hawaii.

Type locality: Makalawena Pond, Hawaii. *Holotype:* Bernice P. Bishop Museum No. 9748.

These nerites are distinguished from *N. rubida* (Pease, 1865b) from Tahiti by their smaller size (shells of *N. rubida* are 5 mm in diameter) and more depressed spire.

Neritina granosa Sowerby, 1825. Fig. 20 A, B. (Synonyms: *Neritina papillosa* Jay, 1893; *N. gigas* Lesson, 1842a.) Length, 42 mm; diameter, 45 mm. *Shell:* dome-shaped to flaring, thin; granular; black. *Spire:* low; apex posterior. *Sculpture:* low, rounded tubercles. *Aperture:* lunate; outer lip flaring laterally; inner lip septum

smooth. *Operculum:* dark red-brown, fan-shaped, with an elongate peg. *Color:* black; aperture blue-white and speckled with black; columellar area white, yellow, or orange. Maciolek (In press) describes the extremely variable shape and shell texture: shells less than 10 mm in diameter are smooth and patterned with light spots; larger shells vary from smooth and domed to rugose and flaring, the rough-shelled forms typical of the lower reaches of streams, the smooth-shelled forms of higher elevations.

These nerites are diadromous, the larvae developing in the ocean and the young migrating upstream, where they settle on boulders (Ford, pers. comm.). Juvenile and mature shells are found in the fresh waters of clear, steep-gradient streams from sea level to elevations of 400 m (Maciolek, In press).

N. granosa was described from a specimen in the Tankerville Collection collected from a "fresh water stream in the South Sea Islands" (Sowerby, 1825). It appears to be endemic to the Hawaiian Islands.

Smaragdia bryanae Pilsbry, 1917. Fig. 19 H, I. Length, 2 mm; diameter, 2 mm. *Shell:* obliquely ovate; smooth and polished; gray spirally banded with white or dark red. *Spire:* short and depressed, of two and one-half whorls. *Sculpture:* smooth and polished, with microscopic growth striae only. *Aperture:* lunate; outer lip thin, sharp, smooth; inner lip finely denticulate its entire length and with one large tooth; septum callused. *Color:* variable — gray spirally banded with white, darker gray, or with bands of dark red lineations.

This nerite is associated with the marine angiosperm *Halophila hawaiiana* on fringing and patch reefs, such as at Anini, Kauai; Kaneohe Bay, Oahu; and near Kaunakakai, Molokai. Shells have also been dredged from depths of 100 m.

S. bryanae was described from the Hawaiian Islands. The association of these nerites with *Halophila* is similar to that reported for *S. rangiana* Recluz with *Thalassia* in the Seychelles (J. D. Taylor, 1968).

Theodoxus cariosus (Wood, 1828). Fig. 20 C, D. (Synonyms: *Neritina sandwichensis* Deshayes, 1838; *N. convexa* "Nuttall," Jay, 1839 (*nomen nudum*); *N. nuttalli* Recluz, 1841; *?N. lugubris* Philippi, 1843; *N. cariosa* Gray, Edmondson, 1933.) Length, 20 mm; diameter, 27 mm. *Shell:* flattened to globose; apex posterior; black but usually eroded. *Spire:* short, of one and one-half whorls. *Sculpture:* marked only by fine lines of growth. *Aperture:* lunate; outer lip thin, sharp, smooth, hinge tooth moderately developed; inner lip with a number of fine, irregular teeth; septum smooth, plane. *Operculum:* calcareous, opaque, blue-gray with bordering red periostracum; rib and peg sharp. *Color:* black with gray or yellow spots, palatal lip and parietal areas white.

These animals are abundant in localized brackish water pools on Hawaii and in the more saline parts of estuaries on others of the windward islands. They are apparently broadly euryhaline, found at salinities of from 1 to 30 ‰ (Maciolek, In press).

T. cariosus is endemic to the Hawaiian Islands.

Theodoxus neglectus (Pease, 1861b). Fig. 20 G, H. (Synonym: *Nerita neglecta* Pease, Edmondson, 1933.) Length, 19 mm; diameter, 14 mm. *Shell:* globose, smooth;

black flecked with white. *Spire:* spire low, two and one-half whorls; the apex often eroded. *Sculpture:* microscopic fine spiral threads. *Aperture:* lunate; outer lip thin, sharp, smooth, hinge tooth strong; inner lip with a number of fine, irregular teeth; septum smooth, plane. *Operculum:* opaque, calcareous, gray with narrow bordering periostracum, rib and peg strong. *Color:* black, peppered with irregular white spots; palatal and parietal regions white.

These snails appear to be euryhaline and are found not only at the seaward edges of basalt and solution benches and in tide pools, but they form a dominant element in brackish water assemblages. They are always found immersed, both on the surface of the substratum and under rocks and rubble. The veligers are the largest of those of the Hawaiian nerites, and metamorphose at one and one-half whorls (J. B. Taylor, 1975). *T. neglectus* is recorded from Pleistocene deposits on Oahu (Ostergaard, 1928).

This species is endemic to the Hawaiian Islands.

Theodoxus vespertinus Sowerby, 1849. Fig. 20 E, F. (Synonyms: *Neritina solidissima* Sowerby, 1849; *N. sandwichensis* Reeve, 1855; *N. tahitensis* Lesson, Tinker, 1952.) Length, 30 mm; diameter, 25 mm. *Shell:* flattened, thin; palatal lip flaring as winglike expansions anteriorly and posteriorly; olivaceous. *Spire:* low; apex posterior. *Sculpture:* fine growth lines. *Aperture:* small, lunate; outer lip flaring, thin, smooth; septum smooth; operculum opaque, porcelaneous, smooth, white with red bordering periostracum, rib curved. *Color:* olive-brown.

These nerites occur near the mouths of rivers and streams, in freshwater and in low salinity parts of estuaries on all the windward islands.

This species is endemic to the Hawaiian Islands.

Additional Records

Nerita albicilla Linnaeus, 1758, (Fig. 19 F) a spirally corded, mottled gray and white species with a horseshoe-shaped aperture, which is widespread throughout the Indo-West Pacific, is occasionally found along shorelines of Maui, Molokai, and Hawaii. *N. turrita* Chemnitz occurs in Pleistocene deposits on Oahu (Ostergaard, 1928). *Neritina aspersa* Sowerby, 1849, a spiny-shelled nerite, was erroneously recorded from the Hawaiian Islands.

Family **Phenacolepadidae**

The members of this family have small, thin, limpetlike shells, circular or oval in outline, with a posteriorly directed, recurved apex. The surface of the shells is variously sculptured with radiating ribs or cancellated, and the shell is white or tinted with brown. A horseshoe-shaped muscle scar opens anteriorly. There is no operculum. The veliger larvae resemble those of nerites (J. B. Taylor, 1975).

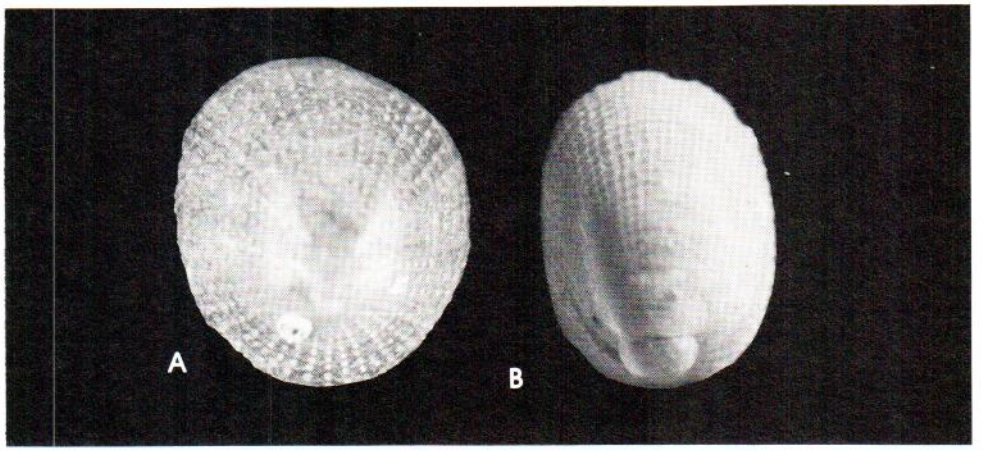


Figure 21.—**Phenacolepadidae.** A. *Phenacolepas granocostata*, length 6 mm. B. *Phenacolepas scobinata*, length 9 mm.

Phenacolepas granocostata (Pease, 1868d). Fig. 21 A. Length, 6 mm; diameter, 5 mm; height, 1.5 mm. *Shell:* patelliform with spreading, flattened margins; fragile; apex posterior but not extending to the margin; white. *Sculpture:* axial ribs crossed by fine spiral striae which form sharp points where the ribs cross the striae; interspaces finely striate; margins smooth. *Color:* white.

This species is known only from beachworn shells.

P. granocostata was described from the Hawaiian Islands.

Phenacolepas scobinata (Gould, 1859). Fig. 21 B. (Synonym: *Scutellina cancellata* Pease, 1861b.) Length, 9.5 mm; diameter, 7 mm. *Shell:* patelliform, fragile; apex extending to the posterior margin; white to red-brown. *Sculpture:* fine axial ribs cancellated by spiral threads of equal or lesser diameter, the axials and spirals forming nodules at the intersections of the ribs; interspaces smooth; margin fimbriated by the external sculpture. *Color:* white or red-brown; interior porcelaneous. *Animal:* foot and proboscis red.

These gastropods are occasionally found under rocks in tide pools; the animals move rapidly over the substrate when disturbed. The veliger larvae are found in the plankton throughout the year (J. B. Taylor, 1975).

P. scobinata was described from Okinawa; it also occurs in Madagascar, New Caledonia, and the Cook and Marshall Islands.

Additional Record

Phenacolepas aculeata (Pease, 1868), distinguished by its prickly, nodular sculpture and finely decussated, raised threads, was described from the Hawaiian Islands but specimens attributable to it have not been recognized in recent years.

Order MESOGASTROPODA

The order Mesogastropoda presently includes not only about half the marine gastropods known, but also most freshwater and terrestrial snails. The great bulk of the marine mesogastropods are in the superfamilies Littorinacea, Rissoacea, and Cerithiacea which Fretter and Graham (1962) term the "corpus" of the order, with an estimated 3,000 species. These gastropods are mostly epifaunal, free-moving on rocks and seaweed, and herbivores, browsing over the substrate by means of the radula consisting primarily of only seven large teeth in each row (Fig. 22). In contrast to the paired organs in the mantle cavity of the archaeogastropods, the gill, kidney, and auricle are unpaired in the mesogastropods, on the left side of the mantle cavity. Fertilization is internal, and copulation is either by insertion of the penis or by a special type of spermatozoa which carry functional sperm from male to female (Fig. 37 A). Egg capsules, elaborated by glandular structures in the female genital system, are deposited on suitable substrates (Figs. 53, 58, 76). In some mesogastropods development is direct with juvenile snails crawling directly from the egg capsule; in others there is a short- or long-lived veliger larva (Figs. 23, 26, 37, 47).

The mesogastropods have diversified in a number of ways. Some are limpetlike or wormlike in form (Hipponicacea, Vermetidae) and are suspension feeders. A number are faunal grazers, feeding on sponges (Triphoridae, Cerithiopsidae), and coelenterates such as sea anemones and corals (Architectonicidae, Epitoniidae). The Eulimacea are parasitic on echinoderms and the Tonnacea and Naticacea are active predators. Differences in protoconch, radula, operculum, and anatomy of the proboscis and esophagus have led Kosuge (1966) to distinguish the Triphoridae, Mathildidae, Architectonicidae, and Epitonacea as a separate group, the Heterogastropoda. Climo (1975) suggests the Heterogastropoda may be primitive shelled members of the subclass Opisthobranchia. I believe such a reorganization premature and follow the more traditional scheme of organization in this account.

Superfamily LITTORINACEA

The members of this superfamily include marine, brackish water, and terrestrial forms. Of the five families in the Littorinacea, two are represented in Hawaiian waters.

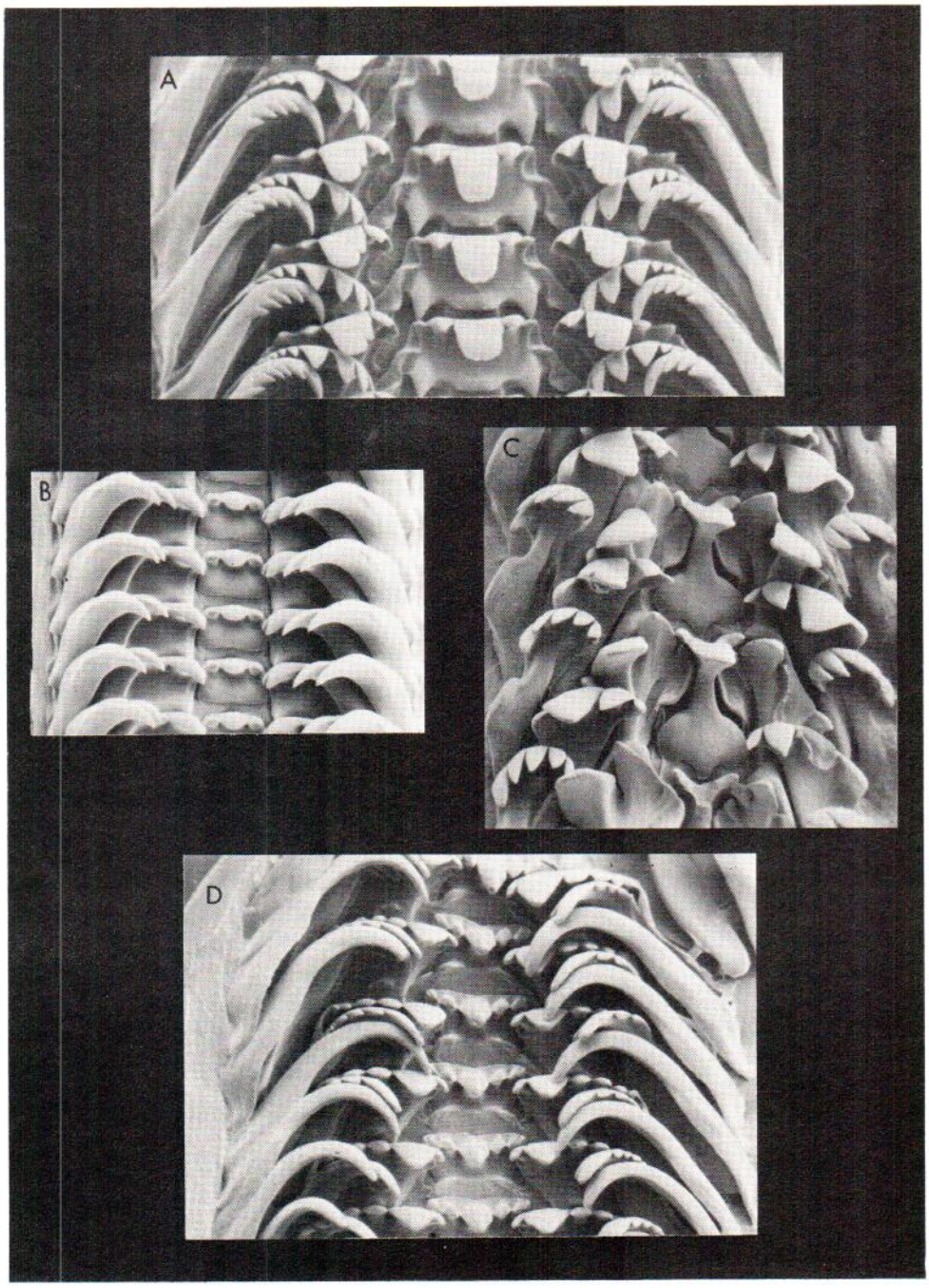


Figure 22.—Taenioglossate radulae. A. *Barleeia calcarea*. B. *Cypraea semiplota*. C. *Nodilittorina picta*. D. *Bittium parcum*.

Family **Littorinidae**

Littorines are the most common mollusks of the high shoreline where they are found in abundance throughout the tropics. Two species are the dominant mollusks of the rocky supratidal region in the islands, the animals feeding on algae and detritus which they rasp from the surface of rocks. Despite their supratidal habit, these mollusks are tied to the sea by their mode of development, for their eggs and larvae develop in the ocean. Fertilization is internal and the fertilized eggs are released into the ocean where development occurs. The Hawaiian littorines do not have distinct breeding seasons but breed continuously for 13 lunar months (Struhsaker, 1966).

Littorine shells are of small to medium size, conical, thin or solid, and there is a small, horny operculum which completely fills the aperture when it is in place.

Littorina coccinea (Gmelin, 1791). Fig. 24 E. Length, 18 mm; diameter, 12 mm. *Shell:* conic-turbinate; with microscopic spiral striae; gray-white. *Spire:* six to nine moderately convex whorls; suture impressed. *Sculpture:* microscopic spiral striae which are more noticeable on the apical whorls than on the last whorl. *Aperture:* subcircular; outer lip thin to moderately thick. *Color:* gray-white; aperture orange-brown.

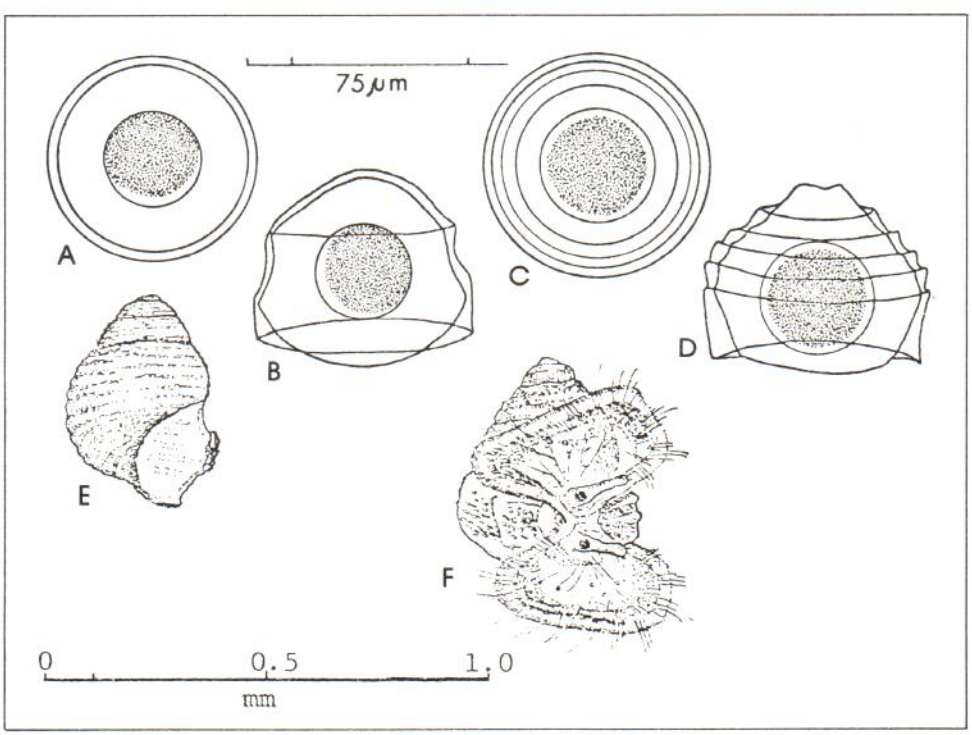


Figure 23.—Stages in the development of littorines. A, B. *Littorina pintado*, dorsal (A) and lateral (B) views of egg capsule in the one-celled stage shortly after spawning. C, D. *Nodilittorina picta*, dorsal (C) and lateral (D) views of one-celled stage of egg capsule. E, F. *Littorina pintado*, premetamorphic protoconch (E) and veliger larva (F). (A-D after Whipple, 1966; E, F from J. B. Taylor, 1975.)

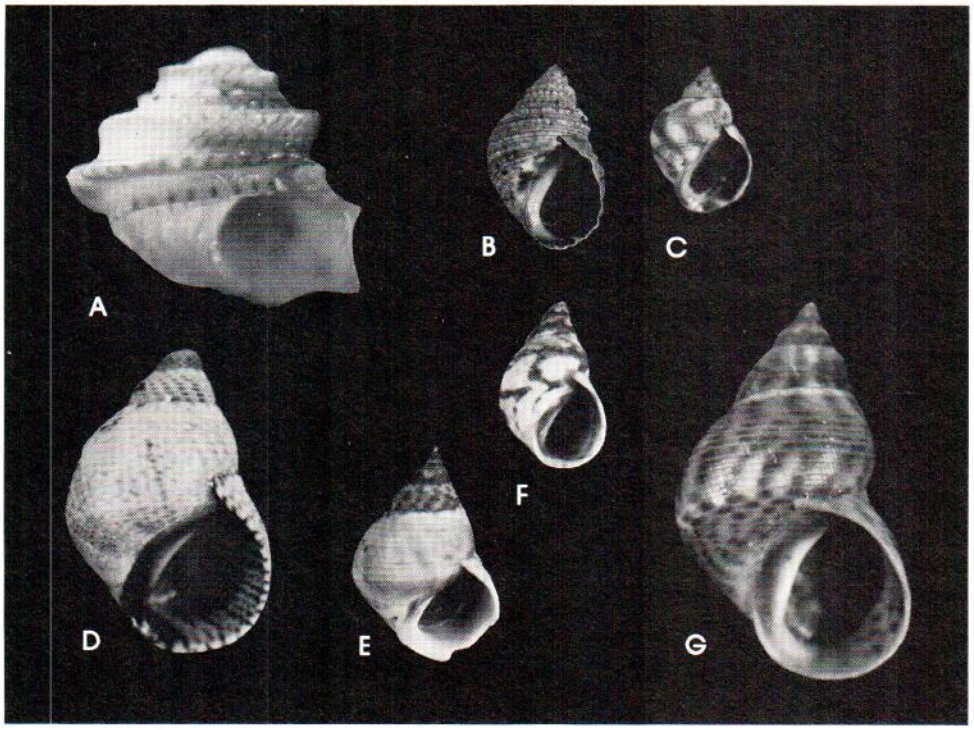


Figure 24.—**Littorinidae.** A. *Peasiella tantilla,* length 5 mm. B. *Nodilittorina picta,* granular form, length 10 mm. C. *N. Picta,* smooth form, length 10 mm. D. *Littorina pintado,* length 10 mm. E. *L. coccinea,* length 12 mm. F. *L. undulata,* length 16 mm. G. *L. scabra,* length 19 mm.

This littorine is rarely found in the islands and the few colonies which are known from the supratidal of Maui, Molokai, and Hawaii may represent only stray colonizations of the species.

L. coccinea is one of the two dominant littorines on the atolls of the central Pacific and ranges throughout the Indo-West Pacific.

Littorina pintado (Wood, 1828). Figs. 6 E; 23 A, B, E, F; 24 D. (Synonyms: *Littorina ambigua* "Nuttall" Philippi, 1848; *L. serialis* Eydoux and Souleyet, 1852.) Length, 9 mm; diameter, 5 mm. *Shell:* conic-turbinate; with microscopic spiral striae; purple-gray freckled with red-brown. *Spire:* five to nine moderately convex whorls; suture moderately impressed. *Sculpture:* microscopic spiral striae. *Aperture:* ovate; outer lip thin to moderately thick. *Color:* purple-gray, freckled with dark brown or black; aperture dark brown.

These littorines are abundant with *Nodilittorina picta* in the supratidal region along all rocky shores from Midway to Hawaii. They are oviparous, shedding their eggs into the water where the young develop in the plankton. The veligers hatch from the egg capsules about four days after spawning and have a long planktonic life (Struhsaker, 1966). *L. pintado* spawns throughout the year, but only during high tides (Struhsaker, 1966). One female may produce 82,000 eggs per year. Fossils of *L. pintado* occur in Pleistocene deposits on Oahu (Ostergaard, 1928).

L. pintado was described from the Hawaiian Islands, but is widely distributed throughout the Indo-West Pacific from East Africa to Clipperton Island *(L. pintado schmitti)* (Rosewater, 1970).

Littorina scabra (Linnaeus, 1758). Fig. 24 G. (Synonyms: *Littorina newcombi* Reeve, 1857; *L. ambigua* Reeve, 1857.) Length, 19 mm; diameter, 11 mm. *Shell:* conic-turbinate; thin; with spiral cords and striae; usually with a mosaic of brown blotches. *Spire:* six to nine convex whorls; suture impressed. *Sculpture:* well-marked spiral cords separated by spiral striae, and axial growth striae. *Aperture:* broadly oval, large; outer lip thin. *Color:* variable — light gray, brown, yellow, or rose, with spiral or axial bands of light or dark brown; columella red-brown.

L. scabra occurs in rather small colonies on protected shores such as are found along breakwaters and harbors. These littorinids are ovoviparous, the eggs developing in the mantle cavity of the female to a late veliger stage, when they are shed into the water and become planktonic. The animals breed throughout the year (Struhsaker, 1966).

L. scabra ranges throughout the Indo-West Pacific from the east coast of Africa to Pitcairn.

Littorina undulata Gray, 1839. Fig. 24 F. Length, 16 mm; diameter, 10 mm. *Shell:* conic-turbinate; smooth; gray and white with light red-brown zigzag lines. *Spire:* five to nine convex whorls; suture impressed. *Sculpture:* spirally incised lines. *Aperture:* ovate; outer lip usually thin. *Color:* light gray or tan, with irregular light red-brown zigzag lines; aperture light yellow-brown; columella dark violet.

Specimens are rarely found. The two or three colonies which are known on Maui, Molokai, and Hawaii consist of very few individuals each and may represent only stray colonizations.

L. undulata is one of the two dominant littorines on the atolls of the central Pacific and occurs throughout the Indo-West Pacific.

Nodilittorina picta (Philippi, 1846b, in part). Figs. 22 C; 23 C, D; 24 B, C. (Synonyms: *Littorina planaxis* "Nuttall" Tryon, 1887; *L. picta marmorata* Philippi, Edmondson, 1933.) Length, 10 mm; diameter, 4.5 mm. *Shell:* conic to turbinate; moderately thick; smooth or with granulose spiral cords; gray to yellow-white with dark brown markings. *Spire:* five or six slightly convex whorls; suture impressed. *Sculpture:* variable — smooth, microscopically spirally striate, or with strong, granulose spiral cords on the spire and last whorl. *Aperture:* ovate; outer lip thin. *Color:* variable — gray to yellow-white with irregular dark brown or black markings; aperture brown or brown and white and mottled; columella usually light tan.

These littorines are abundant in the supratidal region of all rocky shorelines from Necker to Hawaii, but do not apparently occur on calcareous shorelines of the leeward islands.

The shells of *N. picta* are extremely variable in sculpture and color pattern, but no specific differences exist between the smooth and sculptured varieties. Each of the shell forms has survival value under particular ecological conditions, smoother forms surviving best in wave-swept areas and sculptured forms occurring in sheltered localities (Struhsaker, 1968). Spawning occurs during high tides throughout the year, and one female may produce 25,000 eggs per year (Struhsaker, 1966). Development is

oviparous, a swimming veliger hatching about three days after spawning. The larva develops in the plankton, and settles and metamorphoses about 21 days after spawning (Struhsaker and Costlow 1968).

N. picta is endemic to the Hawaiian Islands.

Peasiella tantilla (Gould, 1849). Fig. 24 A. (Synonyms: *Risella parvula* Dunker, 1861; *Trochus diminutivus* Reeve, 1861.) Length, 5 mm; diameter, 5 mm. *Shell:* trochoid with a broad, flat base forming an angular periphery; spirally keeled; yellow-brown. *Spire:* whorls flat; suture indistinct. *Sculpture:* sharp spiral keels extending on to the base. *Aperture:* oval; umbilicus narrow. *Color:* variable — light brown to yellow, variously freckled with white.

These littorines are abundant in the supratidal region along all rocky shores with *Nodilittorina picta* and *Littorina pintado,* but they are more often found in pools and apparently extend farther seaward on benches than do the other species.

P. tantilla occurs throughout the Pacific and possibly also the Indian Ocean.

Family **Eatoniellidae**

The family Eatoniellidae was distinguished by Ponder (1965a) to include gastropods with simple, conical shells, a pegged operculum, and a littorinid type of radula. Eatoniellids are the dominant small algal dwelling mollusks on New Zealand shores where they are micrograzers and microdetritus feeders.

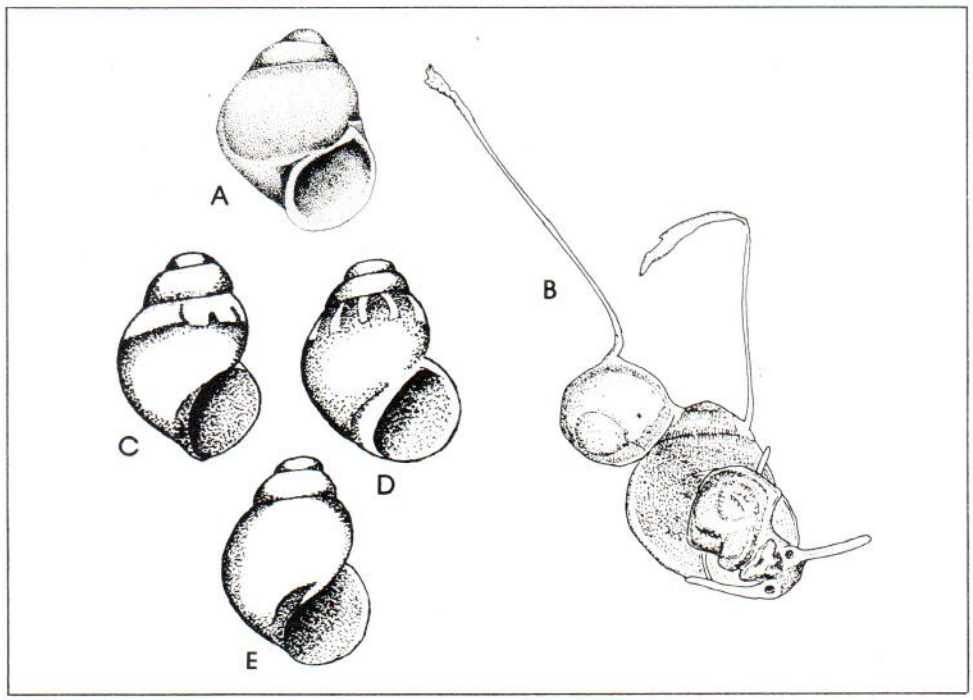


Figure 25.—**Eatoniellidae.** A. *Eatoniella janetaylorae,* length 1 mm. B. *E. janetaylorae,* adult with larva (from J. B. Taylor, 1975.) C, D, E. *E. pigmenta,* length 1 mm.

Eatoniella (Caveatoniella) janetaylorae Kay, new species. Figs. 25 A, B; 31 H-I. Length, 1.25 mm; diameter, 0.5 mm. *Shell:* conic-ovate; smooth; transparent, white. *Spire:* about four convex, inflated whorls, the protoconch not marked off from the teleoconch; suture impressed, false margined. *Sculpture:* microscopic growth striae only. *Aperture:* ovate, slightly angled posteriorly; outer lip convex; peristome continuous; umbilicus a distinct chink. *Operculum:* oval; peg extending from the nucleus past the columellar edge; yellow-brown. *Color:* transparent, white in life; dead shells are opaque white. *Animal:* black.

These minute gastropods are locally abundant in tide pools and are often found in sediments where there are freshwater intrusions. The females deposit a single egg in a spherical capsule on the shell of another eatoniellid (Fig. 25 B) and the juveniles hatch without a functional velum (J. B. Taylor, 1975). Year-round breeding populations have been maintained in laboratory culture, the small mollusks feeding on algal film (J. B. Taylor, 1975).

Type locality: tide pool, Poipu Beach, Kauai. *Holotype:* Bernice P. Bishop Museum No. 9750. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells are distinguished from those of *E. (C.) puniceomacer* Ponder, 1965a, from New Zealand by the white color (the New Zealand shells are pink) and the more convex whorls and from *E. (C.) perforata* Ponder, 1965a, also from New Zealand, by the shorter spire. This species is named for Dr. Jane B. Taylor for her pioneering work on prosobranch veliger larvae in Hawaii.

Eatoniella (Dardaniopsis) pigmenta Kay, new species. Figs. 25 C-E; 31 E-G. Length, 1 mm; diameter, 0.5 mm. *Shell:* conic, barely ovate; smooth; transparent light yellow. *Spire:* barely convex, of three whorls, the protoconch not marked off from the teleoconch; suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* ovate; outer lip convex; umbilicus a shallow depression. *Color:* yellow-brown with lighter flamelike marks below the suture.

These minute gastropods are abundant on frondose algae such as *Sargassum*.

Type locality: fringing reef, Waikiki Beach, Oahu. *Holotype:* Bernice P. Bishop Museum No. 9752. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells are distinguished from the five species included in the subgenus *Dardaniopsis*, all from New Zealand, by the small size, barely convex contours, and the color pattern (Ponder, 1965a). Derivation of name: *pigmentum*, Latin n. — paint. Refers to the color pattern.

Superfamily RISSOACEA

Rissoaceans, because of their small size and variable form, are difficult to classify on the basis of shell characters alone. The nominal family, Rissoidae, is characterized by conical smooth shells and the Rissoinidae by conical shells with axial and transverse sculpture and a short siphon. Other families encompass a wide variety of shell forms including the minute, discoidal, umbilicate shells of the Orbitestellidae and Omalogyridae.

Many of these minute mollusks live in shallow water among seaweed, feeding on diatoms and detritus on the surface of algal filaments (Ponder, 1967). Some have a planktonic larval stage and spend two or three weeks in the plankton. J. B. Taylor (1975) describes the veliger larvae of five species in Hawaiian waters: the velar lobes are unpigmented and unequal in size (Fig. 26), and the protoconch is paucispiral or conical. In other rissoaceans there is no planktonic larval stage, the mollusks hatching as juveniles from large eggs (140 to 320 μm) (J. B. Taylor, 1975). Despite their benthic habit, adult rissoaceans are sometimes found in the plankton, moving up and down the water column by means of a mucous thread produced by the pedal gland in the foot.

Family **Rissoidae**

A variety of shell shapes and sculpture is found in this family, but most of its members are distinguished by the spire being higher than the aperture (Ponder, 1967). Some of the features of the family are shown in Figure 26. The operculum is simple to thick, sometimes with a peg. The animals are distinguished by their eyes in bulges at the base of the cephalic tentacles and the snout is relatively long and mobile. The radula is taenioglossan and the animals feed on diatoms and algal filaments. The sexes

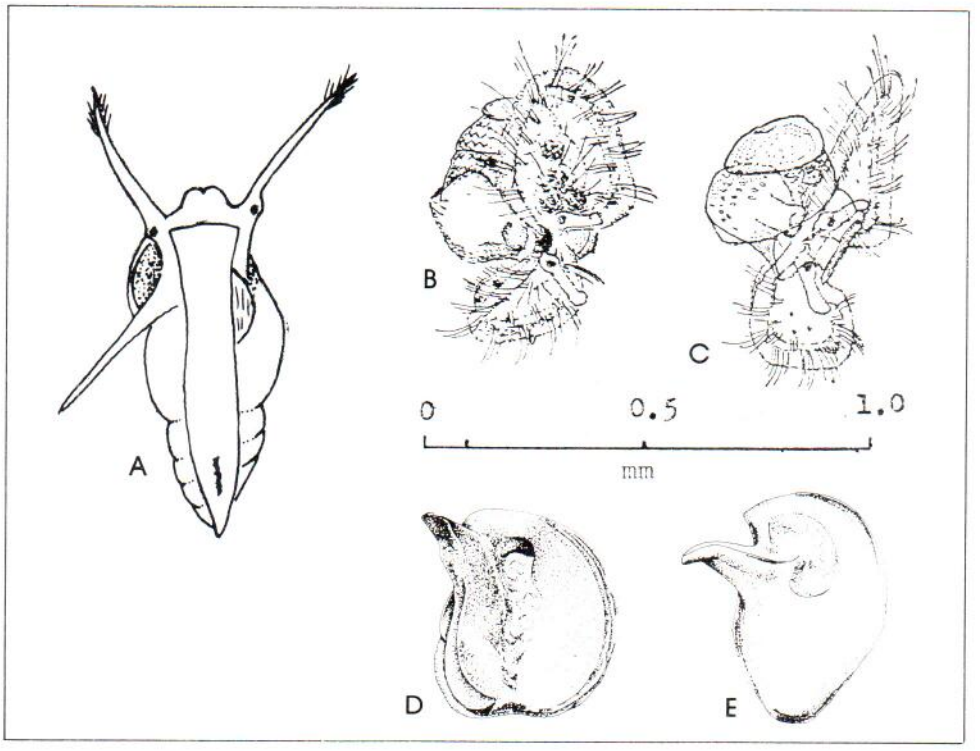


Figure 26.—**Rissoidae.** A. *Vitricithna marmorata*, living animal seen from below. B. Veliger larva of *Rissoina miltozona*. C. Veliger larva of *Zebina tridentata*. D. Operculum, *Barleeia calcarea*. E. Operculum, *Rissoina ambigua*.

are separate, and in the Hawaiian forms, at least, there is usually a free-swimming veliger larva (J. B. Taylor, 1975). Most members of the family are marine.

Subfamily **Rissoinae**

In the Rissoinae the shell is thin to moderately solid, variously sculptured or smooth. The aperture is shallowly channeled anteriorly and posteriorly. The peristome is typically reflected and there is a varix on the outer lip. Six genera, each with a single species, are represented in Hawaiian waters. Their shells are most frequently found at depths greater than 10 m.

Alvinia isolata (Laseron, 1956). Fig. 27 C. Length, 1.75 mm; diameter, 0.75 mm. *Shell:* conic-ovate; with faintly beaded spiral threads; cream splashed with brown. *Spire:* protoconch of one and one-half convex whorls, the apical smooth, the abapical faintly striated; teleoconch of three convex whorls; suture impressed. *Sculpture:* faintly beaded spirals (about 10 on the last whorl), with beading and some axial ribbing more prominent on the apical whorls than on the abapical. *Color:* translucent cream splashed with brown on the spirals just below the suture. *Aperture:* ovate; outer lip thin.

Shells are occasionally found on reefs and in beach drift on north shore beaches of Kauai and Oahu and at Midway, but nothing is known of the habits of the living animals.

A. isolata was described from Christmas Island, Indian Ocean. It is common in the lagoon at Enewetak, Marshall Islands.

Elachisina robertsoni Kay, new species. Fig. 27 A, B. Length, 2 mm; diameter, 1 mm. *Shell:* ovate-conic; convex; with fine spiral threads; transparent white. *Spire:* protoconch of one and one-half smooth whorls; teleoconch of three and one-half convex whorls, each slightly appressed to the preceding whorl. *Sculpture:* microscopic spiral striae; with a rather sharp keel around the umbilicus. *Aperture:* ovate, slightly oblique; outer lip simple, columellar portion narrowly reflected and curving gently into the callus of the parietal wall. *Color:* white.

Shells are most frequently encountered in sediments on fringing reef flats; occasional shells have been collected at depths to 30 m.

Type locality: Maunalua Bay, Oahu in sediments from the reef flat, 1975. *Holotype:* Bernice P. Bishop Museum No. 9754. *Paratypes:* Australian Museum; British Museum (Natural History); United States National Museum.

The Hawaiian shells are distinguished from the two species now recognized in the genus, *E. grippi* Dall, 1918 from San Diego, California and *E. floridianus* (Rehder, 1943) from Florida by the smaller size and fewer whorls. This species is named for Dr. Robert Robertson of the Academy of Natural Sciences of Philadelphia who first drew my attention to the resemblance of the Hawaiian shells to the shells described by Rehder as *Microdochus*.

Parashiela beetsi Ladd, 1966. Fig. 27 D. Length, 1.5 mm; diameter, 0.9 mm. *Shell:* conical, short, thin; with keeled axial ribs; white. *Spire:* protoconch of one and one-half smooth, white whorls; teleoconch of three strongly shouldered whorls; suture deeply impressed. *Sculpture:* sharply defined, keeled axial ribs (9 to 14 on the last whorl) continuous from the suture and curving onto the base; shoulder of each whorl crossed by one or two faint spiral threads which are nodulose where they cross the

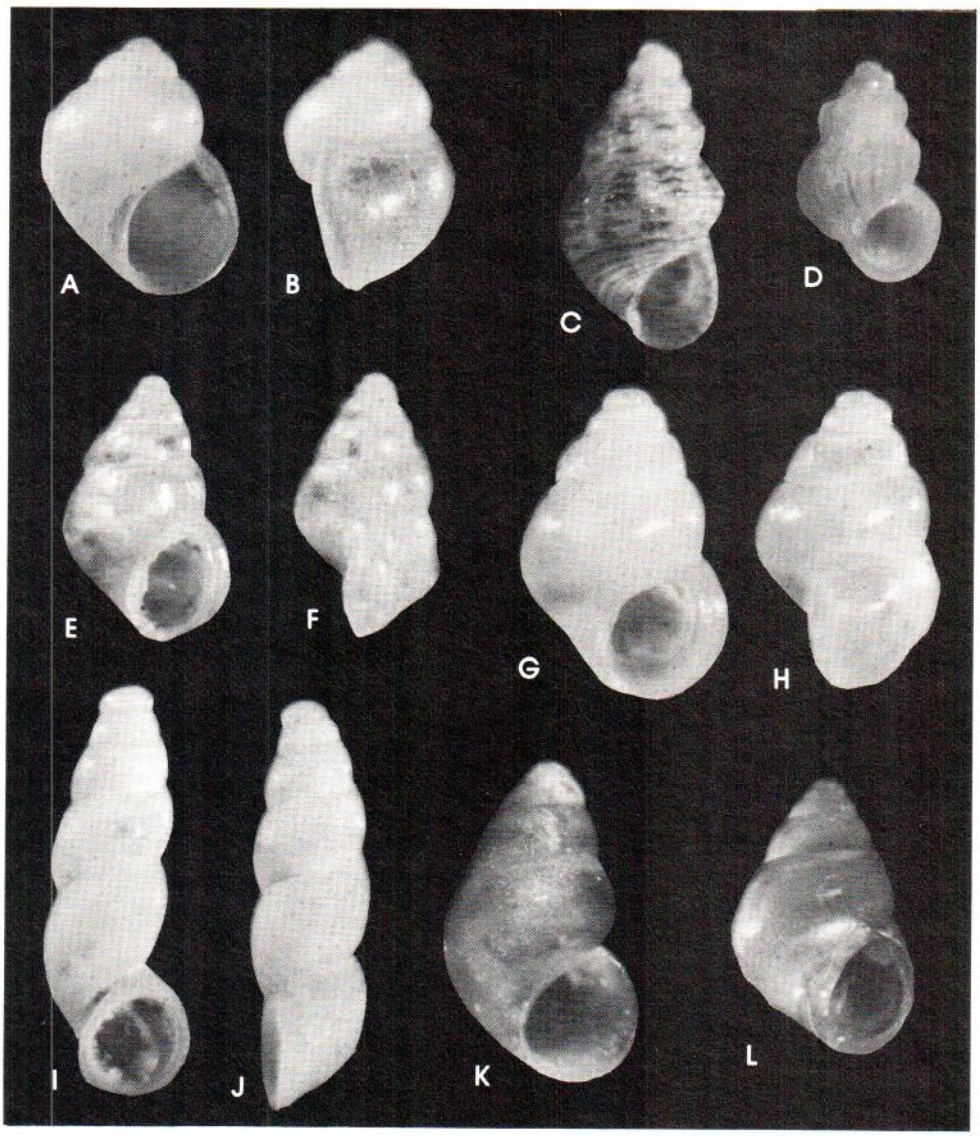


Figure 27.—A, B. *Elachisina robertsoni*, length 2 mm. C. *Alvinia isolata*, length 1.75 mm. D. *Parashiela beetsi*, length 1.5 mm. E, F. *Vitricithna marmorata*, length 1.75 mm. G, H. *Powellisetia fallax*, length 1 mm. I, J. *Nannoteretispira habei*, length 1.25 mm. K. *Barleeia calcarea*, length, 0.75 mm. L. *Assiminea nitida*, length 2.5 mm.

ribs. *Aperture:* subcircular; outer lip with a double wall and thickened behind, forming a low varix. *Color:* white.

These minute rissoinids are occasionally found in the algal mat of tide pools and are common in sediments at depths of from 6 to 30 m.

P. beetsi was described from Recent fossil shells from Enewetak, Marshall Islands (Ladd, 1966). The Hawaiian shells differ from the type description in that they have a variable number of axial ribs and spiral threads.

Powellisetia fallax Kay, new species. Fig. 27 G, H. Length, 1 mm; diameter, 0.75 mm. *Shell:* ovate-conic; outer lip with a thick varix; smooth; glossy, white. *Spire:* protoconch of one and one-half whorls not separate from the teleoconch; teleoconch of three inflated, convex whorls. *Sculpture:* smooth except for microscopic spiral striae on the penultimate whorl. *Aperture:* ovate; peristome continuous; columella nearly vertical; outer lip with a continuous varix; umbilical chink barely noticeable. *Color:* glossy, white.

Shells are locally common in sediments at depths of from 65 to 200 m.

Type locality: Pokai Bay, Oahu, in sediments from depths of 200 m, April, 1978, R. Salisbury collector. *Holotype:* Bernice P. Bishop Museum No. 9756. *Paratypes:* Australian Museum; United States National Museum; British Museum (Natural History).

The genus *Powellisetia* was described by Ponder (1967) to include several small New Zealand rissoids. The Hawaiian shells are distinguished from the type species, *P. porcellana* (Suter, 1908) by the fine striations on the apical whorls, and from the striate shells of *P. subtenuis* (Powell, 1937) by the lack of a distinctive umbilicus. Derivation of name: *fallax,* Latin adj. — false. Refers to the superficial resemblance to shells of *Vitricithna marmorata.*

Vitricithna marmorata (Hedley, 1907). Figs. 26 A; 27 E, F. Length, 1.75 mm; diameter, 1 mm. *Shell:* conical, thin, semitransparent; outer lip with a varix; cream with a peripheral series of opaque white spots and zigzag axial brown lines. *Spire:* protoconch of one and one-half smooth, rather flat white whorls; teleoconch of four convex whorls; suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* subquadrate; outer lip thin, with an external varix; columella with a low median fold and narrow callus. *Color:* transparent in live-collected shells, hyaline in worn shells; with numerous axially oriented zigzag brown lines and spirally banded at the periphery of the whorls by small, angular opaque white spots. *Animal:* exposed parts transparent, mottled with opaque white on the foot and with dark brown on the head; tentacles spotted with opaque white. Cephalic tantacles long, at least one half the length of the foot. Foot simple, anterior blunt, with three series of mucous glands. A single caudal tentacle present.

These rissoids are common at depths of from 3 to 40 m, where they are apparently associated with rubble and they may form the dominant component of micromolluscan assemblages at these depths.

V. marmorata was described from Mast Head Island, Queensland, from depths of 17 to 20 fathoms.

Subfamily **Anabathroninae**

Shells of members of this subfamily are usually solid, variously sculptured or smooth. The aperture is oval or circular, weakly channeled or absent. The operculum is thin to thick, transparent, and oval.

Nannoteretispira habei Kay, new species. Fig. 27 I, J. Length, 1.25 mm; diameter, 0.4 mm. *Shell:* cylindrical; with fine spiral striae; white. *Spire:* protoconch of one and one-half smooth whorls; teleoconch of four inflated whorls, the three abapical whorls about equal in size, the last whorl long and partly uncoiled; suture

constricted. *Sculpture:* microscopic spiral striae. *Aperture:* subcircular; peristome continuous; inner margin of outer lip somewhat thickened; umbilical chink sometimes noticeable. *Color:* white.

Shells are occasionally found in sediments to depths of about 10 m.

Type locality: Kaneohe Bay, Oahu. *Holotype:* Bernice P. Bishop Museum No. 9758. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells differ from those of *N. japonica* Habe, 1961b, from Kyushu, Japan by the lesser number of whorls (four versus seven) and smaller protoconch; they are about half the size of the shells of *N. kelseyi* (Bartsch, 1911) from San Diego, California. This species is named for Dr. Tadashige Habe of the National Science Museum, Tokyo, who first recognized the genus as distinct.

Subfamily **Rissoininae**

This group of rissoids is recognized by the tall-spired, usually solid shell which is variously sculptured or smooth. The aperture is ovate, typically channeled anteriorly and posteriorly. The operculum is simple or thick, bearing a peg. The animal has long, smooth or finely ciliated cephalic tentacles. The snout is long and very extensile. The foot is simple, undivided, with anterior sole and mucous glands. Both caudal and pallial tentacles may be present. Six genera and 17 species are represented in Hawaiian waters.

Isselia hiloense (Pilsbry and Vanatta, 1908). Fig. 28 H. Length, 3 mm; diameter, 1.5 mm. *Shell:* conic-ovate; with beaded axial ribs; white. *Spire:* protoconch of one and one-half glistening white, mamillate whorls; teleoconch of three to five rather straight-sided whorls; suture deep, channeled. *Aperture:* ovate; anterior canal shallow, short, straight; columella glazed and with a fasciole; outer lip simple. *Sculpture:* reticulate — fine axial ribs beaded where they are crossed by spiral threads. *Color:* white.

These rissoids are common on fringing reefs, and shells occasionally occur in sediments to depths of 8 m.

I. hiloense was described from the Hawaiian Islands and also occurs at Christmas Island in the Indian Ocean (Tomlin, 1935a as *Bittium hiloense*).

These shells superficially resemble those of *Merelina* but are distinguished by the siphonal canal.

Merelina granulosa (Pease, 1862). Fig. 28 F, G. Length, 2 mm; diameter, 1 mm. *Shell:* conic-ovate with beaded axial ribs and spiral threads; brown. *Spire:* protoconch of one and one-half whorls, the apical small and smooth, the abapical with spiral striae; teleoconch of four convex whorls; suture wide, shallow. *Sculpture:* strong spiral keels (five on the last whorl) beaded where they are crossed by axial ribs of about equal diameter; apical spiral less prominent than the others; basal spirals on the last whorl smooth. *Aperture:* subcircular; outer lip double-walled and with five short lirae internally. *Color:* dark brown, outer lip sometimes yellow or cream; beachworn shells yellow brown to white.

These rissoinids are common on reefs, occasionally occur in tide pools, and are rarely found in sediments to depths of 20 m.

M. granulosa was described from the Hawaiian Islands.

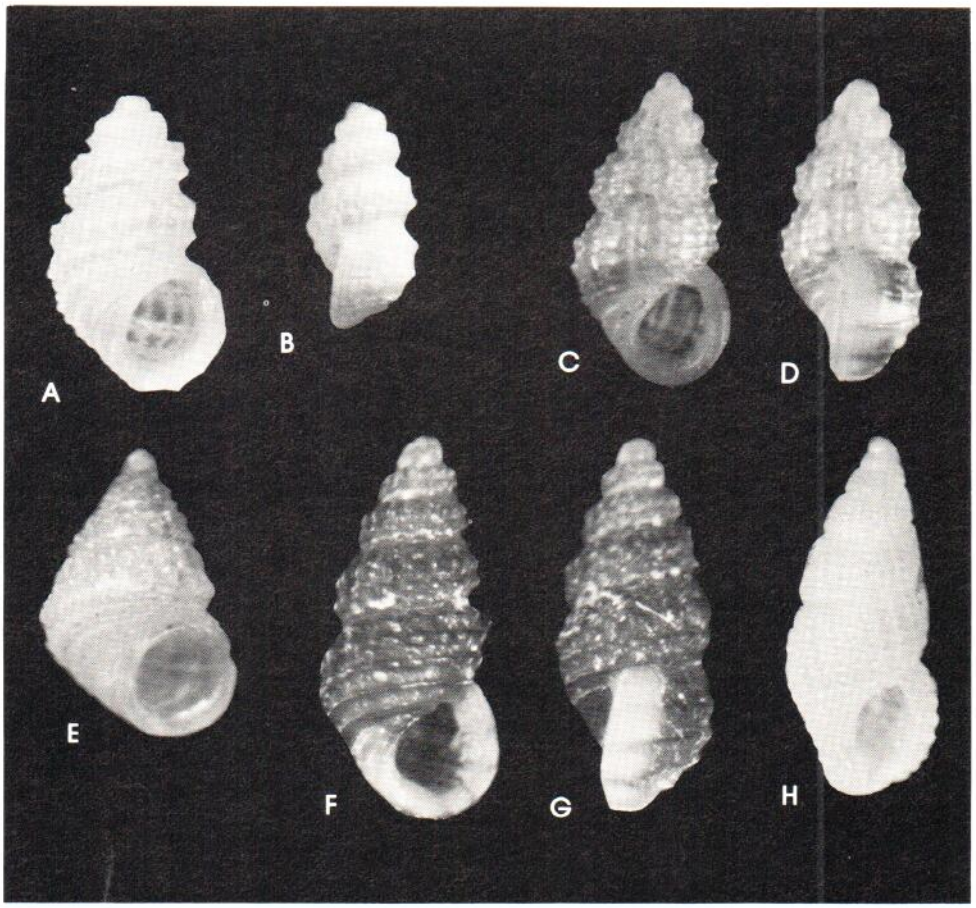


Figure 28.—**Rissoidae.** A, B. *Merelina wanawana*, length 1.75 mm. C, D. *M. hewa*, length 2 mm. E. *M. kenneyi*, length 0.75 mm. F, G. *M. granulosa*, length 2 mm. H. *Isselia hiloense*, length 3 mm.

Merelina hewa Kay, new species. Fig. 28 C, D. Length, 2 mm; diameter, 1 mm. *Shell:* conic-short; with beaded spiral ribs; glistening cream, usually spirally banded with chestnut. *Spire:* protoconch of one and one-half white or light brown whorls, the apical smooth, the abapical disproportionately large, convex and with spiral striae; teleoconch of three convex whorls; suture impressed, wide, shallow. *Sculpture:* clathrate, of beaded spiral cords (three on the last whorl) crossed by strong axial ribs (18 on the last whorl). *Aperture:* subcircular, with five short lirae within; outer lip thick and double-walled. *Color:* glistening cream, usually banded with brown at the sutures and behind the outer lip.

These rissoids are occasionally found in tide pools and on reef flats and benches, but are more common in coral communities at depths of from 6 to 20 m.

Type locality: Honokohau, Hawaii, in sediments at a depth of 8 m, August, 1973. *Holotype:* Bernice P. Bishop Museum No. 9762. *Paratypes:* Australian Museum; British Museum (Natural History); United States National Museum.

Shells of this species have been confused with those of *M. pisinna* (Melvill and Standen, 1896) from the Loyalty Islands by Ladd (1966), who reports them from Miocene cores in the Marshall Islands and Fiji. The shells of *M. pisinna* are smaller (length, 1 mm), have four whorls, and the suture is constricted rather than impressed as in the Hawaiian and Marshall Island shells. The shells of *M. corruga* Laseron, 1956 from New South Wales are similar in shape and size, but the apical whorl of the protoconch is much smaller than it is in the Hawaiian shells. Derivation of name: *hewa*, Hawaiian — wrong. Refers to the confusion over the identity of these shells.

Merelina kenneyi (Ladd, 1966). Fig. 28 E. Length, 0.75 mm; diameter, 0.5 mm. *Shell:* trochiform, solid; with strongly nodulose spiral ribs; white. *Spire:* protoconch of two and one-quarter, bulbous, brown whorls, the abapical whorl with spiral striae; teleoconch of three flat-sided whorls; suture deeply incised. *Sculpture:* strong spiral cords, the apical two cut into sharply projecting nodules on each whorl by columnar axial ribs, and three smooth spiral cords on the last whorl. *Aperture:* circular; inner lip double. *Color:* white.

These rissoids are rarely found in tide pools and on reefs but are common in sediments at depths of 20 to 25 m.

M. kenneyi was described from the Miocene drill cores at Enewetak, Marshall Islands.

Merelina wanawana Kay, new species. Fig. 28 A, B. Length, 1.75 mm; diameter, 0.75 mm. *Shell:* conical; with two prominently beaded spiral cords on each whorl; white. *Spire:* protoconch of one and one-half whorls, the abapical spirally striate; teleoconch of three convex whorls; suture wide, deeply impressed. *Sculpture:* indistinct axial ribs on the apical whorl of the teleoconch; remaining whorls with two prominent spiral keels crossed by well-defined axial ribs rising to sharp protuberances where they cross the keels; base with an additional five spirals. *Aperture:* subcircular; outer lip thick and double-walled. *Color:* white.

These rissoids are rather uncommon, found on reefs and solution benches and to depths of about 33 m.

Type locality: Barbers Point, Oahu, from sediments from a depth of 8 m, Oct. 1970. *Holotype:* Bernice P. Bishop Museum No. 9760. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells are distinguished from shells of other members in the genus by their small size, compact whorls, constricted suture, and prominent, almost prickly sculpture. Derivation of name: *wanawana*, Hawaiian — spiny. Refers to the sculpture.

Pyramidelloides miranda (A. Adams, 1861). Fig. 29 F. Length, 3 mm; diameter, 1 mm. *Shell:* elongate-conic, slender, distorted; with a prominent granular spiral keel on each whorl; white. *Spire:* protoconch of one and one-half smooth, glistening whorls; teleoconch of three flat-sided whorls; suture wide, shallow. *Sculpture:* a prominent beaded spiral keel on each whorl with a lesser spiral below, the two keels joined by fine axial ribs; base of last whorl with three smooth spiral keels. *Aperture:* subcircular; outer lip with a heavy varix. *Color:* white.

Worn shells are rarely found in drift and to depths of 20 m, but nothing is known of the habits of living animals.

P. miranda has been recorded from the Indian Ocean and southern Japan.

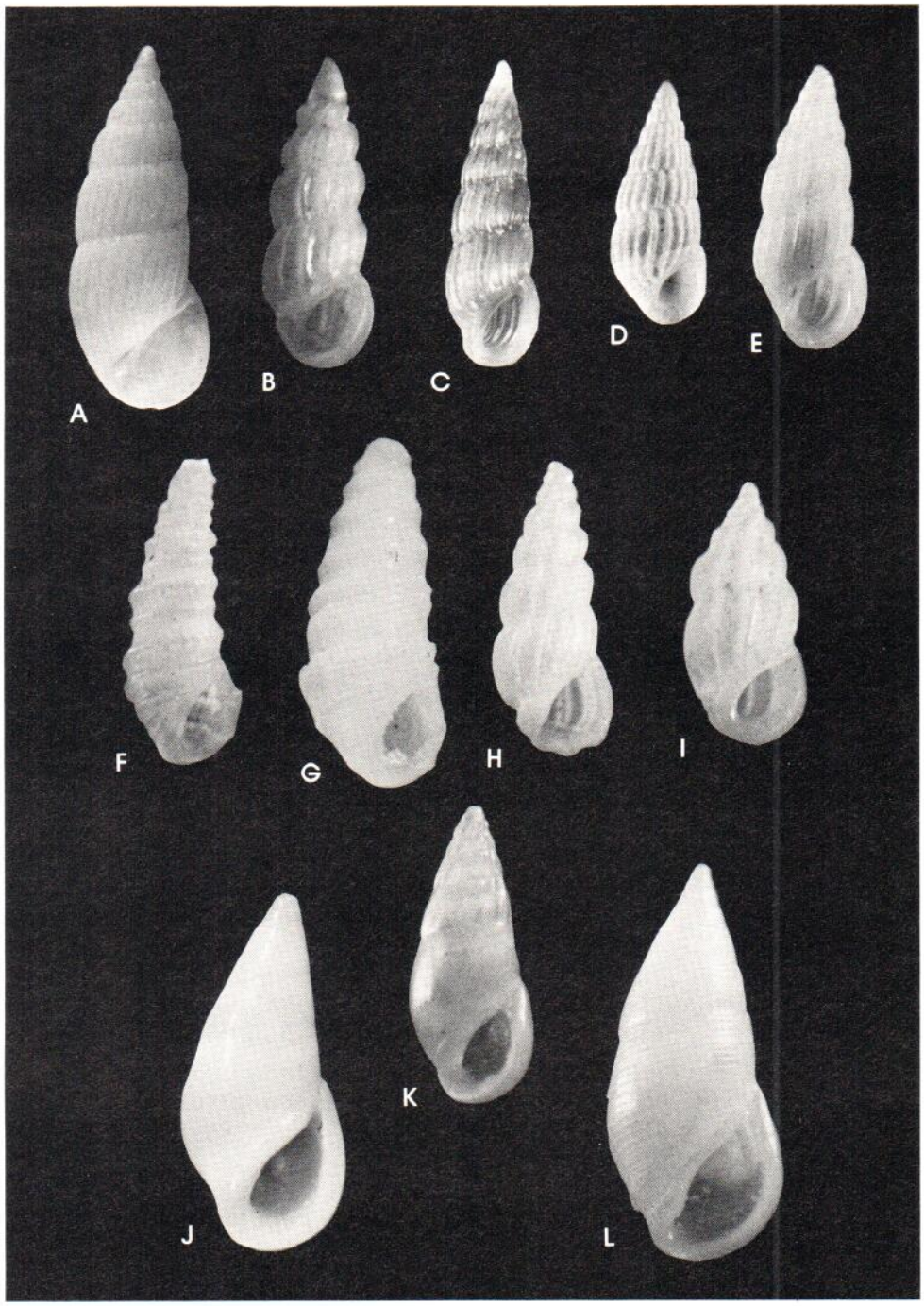


Figure 29.—**Rissoidae.** A. *Rissoina ambigua,* length 6 mm. B. *R. ephamilla,* length 2 mm. C. *Schwartziella gracilis,* length 3 mm. D. *Rissoina miltozona,* length 3 mm. E. *R. pulchella,* length 3 mm. F. *Pyramidelloides miranda,* length 3 mm. G. *P. suta,* length 2 mm. H. *Rissoina turricula,* length 5 mm. I. *Schwartziella triticea,* length 3 mm. J. *Zebina tridentata,* length 6 mm. K. *Z. semiplicata,* length 4 mm. L. *Z. imbricata,* length 9 mm.

Pyramidelloides suta (Pilsbry, 1918). Fig. 29 G. (Synonym: *Odostomia letsonae* Pilsbry, 1918.) Length, 2 mm; diameter, 1 mm. *Shell:* conic-ovate; with two elevated spiral cords on each whorl; white. *Spire:* protoconch of two small, white, conical whorls; teleoconch of five somewhat concave whorls, the apical whorls sometimes bent; suture indistinct. *Sculpture:* two smooth, elevated, spiral cords on the apical whorls, three on the last whorl, the cords contiguous to the suture; remainder of whorls with microscopic axial and spiral striae. *Aperture:* ovate; outer lip thin; columellar fold deeply immersed. *Color:* white.

These rissoids are rare, found occasionally in beach drift and to depths of 63 m.

P. suta was described from the Hawaiian Islands, but was erroneously described as a pyramidellid.

Rissoina ambigua (Gould, 1849). Fig. 29 A. (Synonyms: *Rissoina multicostata* Garrett, 1857; *R. costulifera* Pease, 1862.) Length, 6 mm; diameter, 2 mm. *Shell:* elongate-conic, thick; with fine axial ribs; cream or white. *Spire:* protoconch of three smooth, glistening white whorls; teleoconch of seven slightly convex whorls; suture impressed. *Sculpture:* fine, close-set axial ribs (20 or more on last whorl) and weak spirals in the interspaces between the ribs on the base of the last whorl. *Aperture:* ovate; inner lip concave; outer lip thick; anterior channel deep, undercutting the columella and forming a rounded toothlike projection. *Color:* usually cream or white, occasionally pink, yellow, or cream with brown spiral bands.

These rissoinids are abundant in tide pools and on reefs, less common at depths of 3 to 13 m, and are only occasionally found in sediments at depths to 50 m.

R. ambigua occurs throughout the Indo-West Pacific, from Mauritius and the Seychelles (J. D. Taylor, 1968), and the Cocos-Keeling Islands (Maes, 1967), to Tahiti, the Ellice Islands, the Line Islands (Kay, 1971), and the Marshall Islands (Ladd, 1966).

Rissoina ephamilla Watson, 1886. Fig. 29 B. (Synonym: *Rissoina scalariformis* Watson, 1886.) Length, 2 mm; diameter, 1 mm. *Shell:* elongate-conic, slender, polished; with keeled axial ribs; white. *Spire:* protoconch of four smooth, glistening white whorls; teleoconch of four or five barely convex whorls; suture shallow. *Sculpture:* somewhat sinuous axial ribs (12 or 14 on last whorl), between which are smooth, shallow interspaces equal in diameter to the ribs. *Aperture:* ovate; outer lip thick; siphonal fasciole coarse; anterior and posterior channels broad, shallow. *Color:* white.

R. ephamilla is only occasionally found in tide pools and on reefs but is very common in sediments at depths of 25 to 50 m.

This species was described from the Hawaiian Islands. It has been reported from the Cocos-Keeling Islands (Maes, 1967) and from Recent and Miocene drill holes at Bikini and Enewetak, Marshall Islands (Ladd, 1966).

Rissoina miltozona Tomlin, 1915. Figs. 26 B; 29 D. (Synonyms: *Rissoina balteata* Pease, 1869; *R. costulata* Pease, 1869b, non *R. costulata* Dunker, 1860; *R. cerithiopsis* Pease, 1862, *nomen nudum; R. cerithiiformis* Dunker, Tryon, 1887.) Length, 4 mm; diameter, 1 mm. *Shell:* elongate-conic, straight-sided; with fine axial ribs granulated by spiral grooves; cream banded with brown. *Spire:* protoconch of three inflated, convex whorls, the apical smooth, the next spirally striate, the abapical

with fine axial threads; teleoconch of six flat-sided whorls; suture impressed. *Sculpture:* straight, narrow axial ribs (about 19 on the last whorl) indented by spiral grooves producing a slightly nodulous effect at the intersections. *Aperture:* small, subcircular; inner lip thick and lirate within; anterior and posterior channels shallow. *Color:* white with a brown band encircling the periphery of the last whorl and just above the suture on the other whorls.

These rissoinids are abundant under rocks and rubble in tide pools and on reefs, and common to depths of 65 m.

R. miltozona is distributed throughout the Indo-West Pacific, from Mauritius, the Seychelles, and the Cocos-Keeling Islands (Maes, 1967) in the Indian Ocean to Lifu and the Philippines (Tomlin, 1915), the Line Islands (Kay, 1971), and the Marshall Islands (Ladd, 1966).

Rissoina pulchella (Brazier, 1877). Fig. 29 E. (Synonym: *Rissoina honoluluensis* Watson, 1886.) Length, 3 mm; diameter, 1 mm. *Shell:* elongate-conic, slender; with fine axial ribs; cream or pink. *Spire:* protoconch of three convex whorls with granular spiral striae; teleoconch of five slightly convex whorls; suture barely impressed. *Sculpture:* fine axial ribs (16 to 18 on last whorl) separated by wide, shallow interspaces. *Aperture:* ovate; outer lip thick; anterior and posterior channels broad and shallow. *Color:* white, occasionally pink or white with brown bands.

R. pulchella is occasionally found in tide pools on Hawaii and is common in sediments at depths of 20 to 65 m off Oahu.

R. pulchella was described from Barnard Island, Queensland, and *R. honoluluensis* from the Torres Straits and the Hawaiian Islands.

Rissoina turricula Pease, 1861b. Fig. 29 H. Length, 5 mm; diameter, 1.5 mm. *Shell:* conical, stout, turreted; with strong axial ribs and spirally striate interspaces; white. *Spire:* protoconch of one and one-half smooth, white whorls; teleoconch of six convex, angulated whorls; suture deeply impressed. *Sculpture:* closely spaced, strong axial ribs (12 or 14 on the last whorl), the interspaces of about equal diameter and with fine spiral striae; last whorl encircled by a groove at the base. *Aperture:* ovate, anterior channel broad and shallow. *Color:* white.

R. turricula is a commonly occurring species under rocks and rubble in tide pools and on reefs, and shells are occasionally found in sediments to depths of 3 m.

This species is distributed throughout the Indo-West Pacific, from Mauritius and the Red Sea (Nevill, 1885), and the Cocos-Keeling Islands (Maes, 1967) to the Line Islands (Kay, 1971), and the Marshall Islands. It occurs in Miocene formations in Fiji and at Enewetak, Marshall Islands (Ladd, 1966).

Schwartziella gracilis (Pease, 1861b). Fig. 29 C. (Synonym: *Rissoina gracilis* Garrett, 1873b.) Length, 3 mm; diameter, 1 mm. *Shell:* elongate-conic, slender; with sinuous axial ribs; red-brown. *Spire:* protoconch of three glossy white whorls; teleoconch of six slightly convex whorls; suture shallow, margined. *Sculpture:* slightly oblique and sinuous axial ribs (14 on the last whorl) extending the length of each whorl, with smooth interspaces of equal diameter. *Aperture:* subcircular; outer lip thick; inner lip callused; anterior channel broad and shallow. *Color:* red-brown.

These rissoinids are often found among the byssal threads of the bivalve *Isognomon perna* under rocks in tide pools and on reefs; and shells occasionally occur in sediments to depths of 50 m.

S. gracilis appears to be distributed throughout the Indo-West Pacific. Garrett's species was described from Fiji, and Pleistocene fossils occur in Tonga (Ladd, 1966). Shells from Mauritius are indistinguishable from Hawaiian shells, and *R. woodmasoniana* Nevill, 1884, from the Andaman Islands may be a synonym.

Schwartziella triticea Pease, 1861b. Fig. 29 I. Length, 3 mm; diameter, 1 mm. *Shell:* stoutly conical; with strong, keeled axial ribs; white. *Spire:* protoconch of two and one-quarter smooth, white whorls; teleoconch of four or five barely convex whorls; suture shallow. *Sculpture:* smooth, strong keeled axial ribs extending the length of each whorl (9 on the last whorl), the interspaces wider than the ribs, gently channeled and smooth. *Aperture:* oval, with a sinus at the abapical shoulder; outer lip thickened by a ridged rim; basal margin reflected outward; parietal region covered by a thin callus. *Color:* white.

S. triticea is very common under rocks and rubble on reefs and in tide pools and shells are occasionally found in sediments to depths of 15 m.

This species occurs throughout the Indo-West Pacific from Mauritius, Ceylon, and the Andamans (Nevill, 1885) to the Cocos-Keeling Islands (Maes, 1967) and the Marshall Islands (Ladd, 1966).

Zebina imbricata (Gould, 1861). Fig. 29 L. (Synonym: *Rissoina striatula hawaiensis* Pilsbry, 1920.) Length, 9 mm; diameter, 3 mm. *Shell:* elongate-conic, stout; with microscopic spiral striae; white. *Spire:* protoconch of four acute, smooth, flat-sided whorls; teleoconch of six inflated, convex whorls; suture barely impressed. *Sculpture:* microscopic spiral threads crowding each whorl. *Aperture:* ovate; parietal region covered by a thin callus; channeled anteriorly and posteriorly. *Color:* white.

Worn shells are uncommonly found in drift and to depths of 40 m, but nothing is known of the habits of the living animals.

Z. imbricata was described from the China Seas and *Rissoina striatula* Pease, 1868b, from the Tuamotus. Pilsbry (1920) distinguished the Hawaiian shells because of their small size but the distinction appears unwarranted.

Zebina semiplicata (Pease, 1862). Fig. 29 K. Length, 4 mm; diameter, 1.5 mm. *Shell:* subulate, slender; shining white. *Spire:* protoconch of a single smooth mamillate white whorl; teleoconch of six barely convex whorls; suture but slightly impressed. *Sculpture:* the three apical whorls obscurely axially ribbed, abapical whorls smooth. *Aperture:* ovate, usually with two or three denticles and with fine, longitudinal posterior striae; barely channeled. *Color:* white.

The habits of the living animals are not known, and shells are uncommon on reefs and to depths of 15 m.

This species is distributed throughout the Indo-West Pacific. Pease described it from Howland Island and it has been recorded from Mauritius and the Cocos-Keeling Islands (Maes, 1967).

The shells of *Z. semiplicata* are distinguished from those of *Z. tridentata* by their smaller size and more slender shape.

Zebina tridentata (Michaud, 1830). Figs. 26 C; 29 J. (Synonym: *Rissoina crassilabrum* Garrett, 1857.) Length, 6 mm; diameter, 3 mm. *Shell:* subulate, stout;

shining white. *Spire:* protoconch of a single, smooth, mamillate white whorl; teleoconch of six slightly convex whorls; suture barely impressed; last whorl large and inflated. *Sculpture:* apical whorls often obscurely axially ribbed; abapical whorls smooth. *Aperture:* ovate, usually with two or three denticles on the inside of the outer lip but these may be absent; posterior channel slight. *Color:* white.

These rissoinids appear to be sand-dwellers on the reefs; shells are occasionally found in sediments to depths of 15 m.

This species is distributed throughout the Indo-West Pacific, from Mauritius and the Cocos-Keeling Islands (Maes, 1967) to the Marshall Islands (Ladd, 1966).

Subfamily **Barleeinae**

The shells of the Barleeinae are simple, smooth, and typically red-brown. The operculum is thick with a straight peg and a longitudinal, thick ridge. The animals have rather short tentacles and there are both posterior and anterior mucous glands on the sole of the foot (Fig. 26 D).

One species is found in the Hawaiian Islands.

Barleeia calcarea Kay, new species. Figs. 22 A; 26 D; 27 K. Length, 0.75 mm; diameter, 0.5 mm. *Shell:* conic-ovate; thin; smooth; brown. *Spire:* four convex whorls, the apical whorl flat, not separated from the others; suture barely impressed. *Sculpture:* incremental growth lines only. *Aperture:* subcircular; base of lip projecting slightly at columella; outer lip thin. *Operculum:* red, thick; with a straight peg and a thick longitudinal ridge. *Color:* red-brown, often encrusted with calcareous algae.

These gastropods are abundant on algae, especially *Padina* and *Spyridia,* forming a dominant element in molluscan assemblages in tide pools and on solution benches. *B. calcarea* is one of the intermediate hosts for the cercaria of a trematode occurring in the intestine of the goby *Bathygobius fusca* at Diamond Head, Oahu (D. E. Watson, 1961).

Type locality: Poipu, Kauai. *Holotype:* Bernice P. Bishop Museum No. 9764. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells are distinguished from the well-known *Barleeia rubra* (J. Adams, 1797) (see Ponder, 1967) and other species in the genus by the contours of the shell and by details of radular structure. Derivation of name: *calcarius,* Latin — of lime. Refers to the calcareous deposition frequently found on the shells.

Family **Assimineidae**

This family is composed of a group of small snails which are amphibious and air-breathing, found primarily in brackish water estuaries on tropical and semitropical continental coastlines and islands. There is a single genus, *Assiminea,* with between 50 and 60 species, most of which are reported from southeast Asia (Abbott, 1958). The shells are simple, elongate-conic to elongate-globose, and of various shades of brown. The animals are thought to be dioecious, with the males bearing a large, external penis, and the eggs laid singly in gelatinous masses (Abbott, 1958). The veligers of *Assiminea grayana* from Europe are free-swimming (Sander, 1950).

Assiminea nitida (Pease, 1865a). Fig. 27 L. Length, 2.5 mm; diameter, 1.5 mm. *Shell:* conic; smooth; with a callus pad; brown. *Spire:* protoconch of one and one-half whorls not distinctly marked off from the teleoconch; teleoconch of four or five convex whorls; suture impressed, false-margined. *Sculpture:* a fine, distinct spiral thread below the suture and microscopic growth striae. *Aperture:* ovate; outer lip thin; umbilicus filled by a callus pad; columella strong, curved. *Color:* red-brown to yellow-brown.

These gastropods are common high on the shoreline under rubble with the pulmonates *Melampus* and *Laemodonta*.

A. nitida is widespread in the Pacific, recorded from the Society, Marquesas, Cook, and Marshall islands, Guam, and the Philippines. Abbott (1958) distinguishes seven subspecies, one each from Polynesia, the Marshall Islands, and Guam, and four from the Philippine Islands.

Family **Rastodentidae**

This family was proposed to include gastropods with minute (1 to 2 mm) conical shells and an unusual rachiglossan radula apparently associated with the animals' habit of feeding on the polyps or zooids of hydroids and bryozoans (Ponder, 1966b). The shells are smooth *(Rastodens)* or spirally corded *(Tridentifera)*, and the whorls are distinctly margined. They are distinguished from the shells of *Barleeia* by their white color, polished texture and narrower apices. The aperture is oval to circular, the peristome not greatly thickened, and the outer lip is strongly excavated. The oval operculum has a peg.

A penis and ctendium are lacking, features which may be associated with small size, and the enlarged, ciliated osphradium presumably maintains pallial circulation (Ponder, 1966b). In New Zealand these mollusks are associated with a hard bryozoan substrate or coarse shell on which bryozoans and hydroids live (Ponder, 1966b). The two species described from Hawaiian waters are found subtidally, most often on the leeward coastlines of Oahu and Hawaii.

Rastodens brevilabiosa Kay, new species. Fig. 30 A. Length, 2 mm; diameter, 0.75 mm. *Shell:* conical; whorls falsely margined; transparent, white. *Spire:* protoconch of one blunt whorl not distinctly set off from the teleoconch; teleoconch of three somewhat convex whorls, suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* subcircular; peristome continuous; columella and outer lip thin, deeply concave; outer lip sharp, barely projecting. *Color:* transparent, white.

These gastropods are common in beach drift on the leeward shores of Oahu and in sediments to depths of 10 m on the Kona coast of Hawaii.

Type locality: Nanakuli Beach, Oahu. *Holotype:* Bernice P. Bishop Museum, No. 9766. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells of *R. brevilabiosa* are distinguished from those of *R. pseudomarginata* Ponder, 1966b, by the contours of the whorls, and from those of *R. labiosa* by their smaller size, transparency, and nonprojecting outer lip. Derivation of name: *brevis, labium,* Latin — short, lip. Refers to the nonprojecting outer lip.

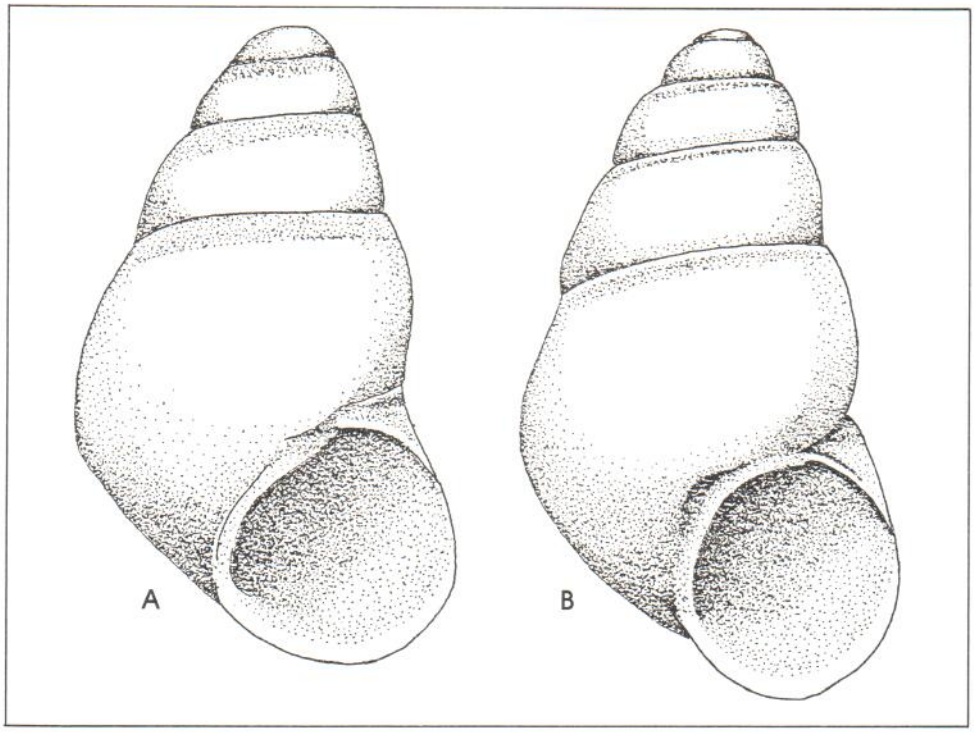


Figure 30.—**Rastodentidae.** A. *Rastodens brevilabiosa*, length 2 mm. B. *R. labiosa*, length 2.5 mm.

Rastodens labiosa Kay, new species. Fig. 30 B. Length, 2.5 mm; diameter, 1 mm. *Shell:* conical; solid; whorls falsely margined; outer lip projecting forward; white. *Spire:* protoconch of about one smooth, flat whorl not distinctly set off from the teleoconch; teleoconch of four and one-half to five slightly convex whorls; suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* subcircular; peristome continuous; columella and inner lip thin, deeply concave; outer lip sharp and projecting downward. *Color:* opaque white.

These gastropods are abundant in beach drift on the leeward coast of Oahu and have been found to depths of 10 m in sediments on the Kona coast of Hawaii.

Type locality: Nanakuli Beach, Oahu. *Holotype:* Bernice P. Bishop Museum, No. 9768. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The Hawaiian shells are distinguished from *R. pseudomarginata* Ponder, 1966b, from New Zealand primarily by the contours of the whorls, and the shells of this species from those of *R. brevilabiosa* by their larger size, greater number of whorls, and opaque white color. Derivation of name: *labium*, Latin — lip. Refers to the projecting outer lip.

Family **Vitrinellidae**

This family includes a variety of minute shells most of which are apparently transparent when the animal is alive but become opaque white after death. The shells

are low and flattened, almost always wider than high, porcelaneous, umbilicate, often with a callus pad, and the surface is smooth or ornamented with various types of sculpture. The protoconch is smooth and glassy, usually of about two whorls which terminate in a low, distinct varix. The operculum is horny, circular, and multispiral.

Because most of the shells are small and known only from specimens found in beach drift, a number of gastropods have been included in the family which have since been transferred to other families, especially the Liotiidae (Trochacea) and Skeneidae. Pilsbry and Olsson (1952) suggest that vitrinellids live under stones at the tide line and

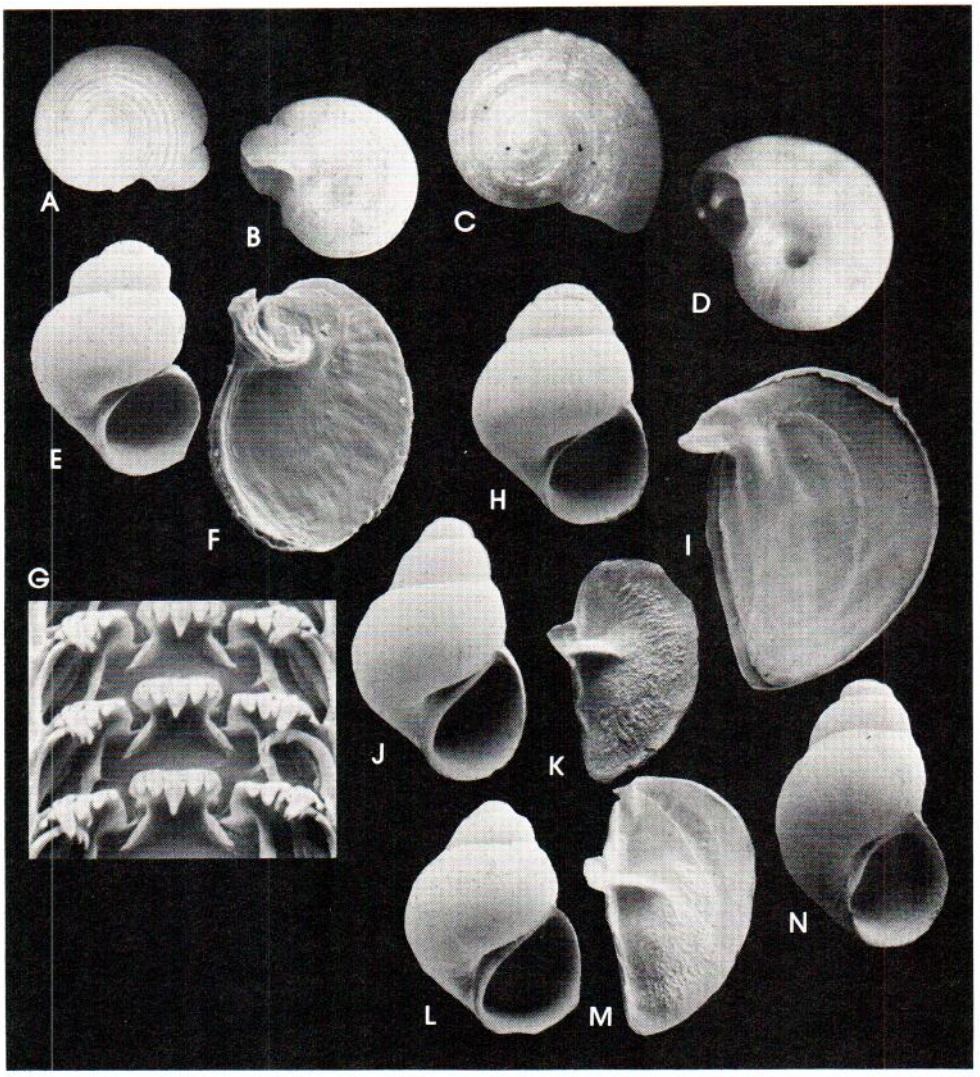


Figure 31.—A, B. *Elacorbis callusa*, diameter 3 mm. C, D. *Teinostoma sulcata*, diameter 4 mm. E - G. *Eatoniella pigmenta*. E. Shell, length 1 mm, holotype. F. Operculum. G. Three rows of radular teeth, 1800X. H, I. *E. janetaylorae*. H. Shell, length 1 mm, holotype. I. Operculum. J. *Rissoella longispira*, length 1.5 mm, holotype. K, Operculum. L. *R. confusa confusa*, length 1 mm. M. Operculum. N. *Rufodardanula conica*, length 1 mm.

at greater depths, and that they are sometimes associated with rough shells such as *Spondylus* and *Chama*, and under the scales of annelid worms and on the gills of chitons.

Elacorbis callusa (Laseron, 1958a). Fig. 31 A, B. Height, 1.5 mm; diameter, 3 mm. *Shell:* spire depressed; with a small umbilicus; fine spiral keels; white. *Spire:* protoconch of about one and one-half smooth, glassy whorls; teleoconch of three whorls, last whorl the largest, periphery rounded; suture impressed. *Sculpture:* fine, narrow spiral keels, about 10 visible on the last whorl from above and five or six below the periphery; umbilical area smooth. *Aperture:* oblique; peristome entire with a band of callus extending on to the last whorl; umbilicus narrow, deep. *Color:* white.

These shells are occasionally found in beach drift.

E. callusa was described from Darwin, Australia.

Teinostoma sp. cf. *sulcata* (A. Adams, 1850 A). Fig. 31 C, D. Height, 1.2 mm; diameter, 4 mm. *Shell:* depressed; umbilicate; with fine spiral lines; white. *Spire:* protoconch of one and one-half slightly smooth, elevated whorls; teleoconch of two and one-half rounded whorls, the last whorl inflated and the periphery rounded. *Sculpture:* numerous fine spiral lines visible on all but the early whorls, base smooth. *Aperture:* subcircular; peristome entire; umbilicus deep and with three or four bars of callus. *Color:* white.

These shells are rarely found in beach drift but nothing is known of the habits of the living animals.

T. sulcata was described from the Philippine Islands.

Family **Orbitestellidae**

The orbitestellids have minute, discoid shells with the spire slightly raised or sunken, and a wide umbilicus. The aperture is quadrate, the dorsal part of the outer lip typically bent downward slightly in front of the posterior sinus. The operculum is circular and multispiral.

Orbitestella regina Kay, new species. Fig. 32 D-F. Height, 0.5 mm; diameter, 2 mm. *Shell:* discoid; with a single beaded carina and transverse riblets; white. *Spire:* flat, apex sunken; protoconch of a single smooth whorl; teleoconch of two whorls. *Sculpture:* periphery of last whorl with a single, strong, beaded carina and with axial riblets crossing the whorl to the carina, about 26 across the last whorl. *Aperture:* subcircular, peristome continuous; outer lip thin, angled by the carina; umbilicus wide and deep. *Color:* white.

These minute mollusks are common in tide pools and in sediments to depths of 50 m.

Type locality: Keahole Point, Hawaii. *Holotype:* Bernice P. Bishop Museum No. 9770. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells of *O. regina* are distinguished from those of the type of the genus, *O. bastowi* (Gatliff, 1906) from Victoria, Australia, by the distinct transverse riblets. This species is named for Miss Regina Kawamoto who has picked hundreds of shells in this size range from sediments in her studies of micromollusks.

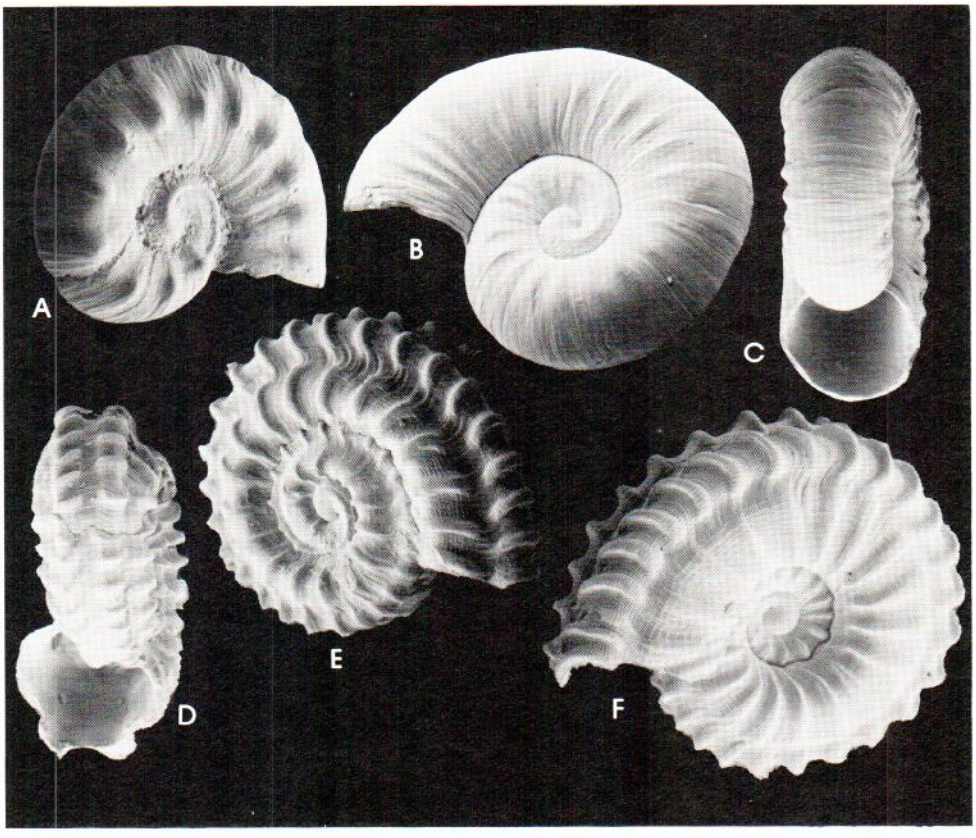


Figure 32.—A - C. *Omalogyra japonica*, diameter 0.5 mm. D - F. *Orbitestella regina*, diameter 2 mm, holotype.

Family **Omalogyridae**

The omalogyrids are minute planispiral, umbilicate snails in which the sculpture is identical and the protoconch is equally visible on both sides. The shells of most species are brown. In the minute British omalogyrid, *Omalogyra atomus*, the shell is carried with the aperture directed forward and the plane of coiling is oriented anterior-posteriorly so that the animal appears bilaterally symmetrical when crawling (Fretter and Graham, 1962).

Omalogyra japonica (Habe, 1972). Fig. 32 A-C. Height, 0.42 mm; diameter, 0.5 mm. *Shell:* planorboid; widely umbilicate; with axial ribs; brown. *Spire:* protoconch of one whorl; teleoconch of about three whorls; suture deep and constricted. *Sculpture:* from 16 to 18 axial ribs on the last whorl, the ribs becoming obsolete at the periphery. *Color:* brown.

These minute gastropods are common on algae such as *Padina* in tide pools and on solution benches; shells have been found in sediments to depths of 100 m.

O. japonica was described from Honshu, Japan, and is also found at Fanning Island (Kay and Switzer, 1974).

Family **Rissoellidae**

Rissoellid shells are minute, usually less than 2 mm in length, with a short spire, convex whorls, and globose last whorl. The shells are fragile, and either partially or wholly transparent. Apart from their rather nondescript shells, rissoellids are distinguished by three features: the occurrence of four "tentacles" in the head region; the shape of the operculum; and the pigmentation of the animal body.

The head of rissoellids is marked by what on first glance appears to be two pairs of tentacles (Fig. 33); inspection suggests, however, that while the outer tentacles are cephalic tentacles, the inner projections are bifid lobes above the snout, variously referred to as anterior projections (Robertson, 1961), oral lobes (Ponder, 1966a), and "false tentacles" (Abbott, 1974). These lobes may be short and club-shaped or as long and slender as are the cephalic tentacles. The operculum is semicircular, the columellar edge flat but angled and with a blunt projection emerging from it. All rissoellids for which there is information on the living animal appear to have distinctly pigmented bodies: black, yellow, or tan, often spotted or banded with yellow, rose or white (Fretter, 1948; Robertson, 1961; Ponder, 1966a).

More than 25 rissoellids have been described; most are known from the southern hemisphere (Robertson, 1961; Ponder, 1966a). Fretter (1948) has suggested that they have some affinities with the opisthobranchs, but they are usually included in the Rissoacea because of their taenioglossan radula.

These animals are hermaphroditic. Development is direct, but the adults may be found in the plankton of coastal waters in which they are caught up by the mucous thread secreted from a sole mucous gland (J. B. Taylor, 1975). They are found on seaweed in shallow water, where they feed on diatoms, detritus and algal filaments (Fretter, 1948).

Rissoella sp. cf. *confusa confusa* Ponder and Yoo, 1977. Figs. 31 L, M; 33 C, D. Length, 1 mm; diameter, 0.5 mm. *Shell:* minute, ovate; umbilicate; thin, transparent. *Spire:* protoconch of about one whorl, not distinct from teleoconch; teleoconch of two whorls, convex; suture impressed. *Sculpture:* microscopic growth striae on an otherwise smooth and glossy surface. *Aperture:* ovate; outer lip thin; columellar callus raised, forming a ridge next the umbilical shelf; umbilicus narrow, short, deep. *Operculum:* ovate; with a peg. *Color:* semitransparent, glassy. *Animal:* black, spotted with chrome yellow; anterior margin of foot bilobed; head lobes and cephalic tentacles about the same length.

These minute gastropods are common in frondose algae in tide pools and on fringing reef flats. Adults are sometimes found in the plankton where they may appear traversing the water column on mucous threads produced by the pedal gland of the foot.

The shells and animal are similar to those of *R. confusa confusa* described from Lizard Island, Queensland, and found also in the Solomon Islands and New Caledonia (Ponder and Yoo, 1977).

Rissoella longispira Kay, new species. Figs. 31 J, K; 33 A, B. Length, 1.5 mm; diameter, 1 mm. *Shell:* minute, conic-elongate; umbilicate; thin, semitransparent. *Spire:* protoconch of about one whorl not well separated from the teleconch; teleoconch of three slightly inflated whorls; suture impressed. *Sculpture:* microscopic growth striae on an otherwise smooth and shiny surface. *Aperture:* ovate; outer lip

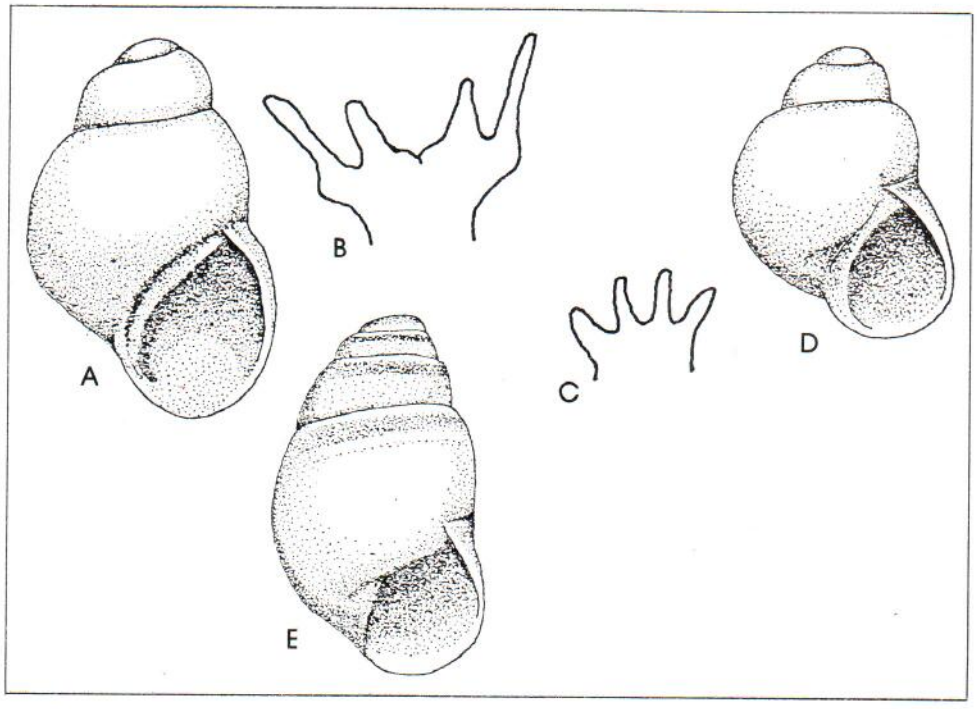


Figure 33.—**Rissoellidae** and **Cingulopsidae.** A, B. *Rissoella longispira,* shell length, 1.5 mm (A); semidiagrammatic dorsal view of head (B). C, D. *R.* sp. cf. *confusa confusa,* shell length 1 mm (D); semidiagrammatic dorsal view of head (C). E. *Rufodardanula ponderi,* length 1 mm.

thin; columellar raised forming a ridge next to the umbilical shelf; umbilicus elongate. *Operculum:* ovate; with a peg. *Color:* transparent, glassy, abapical whorls lightly false-margined. *Animal:* gray spotted with rose; head lobes shorter than the cephalic tentacles.

These rissoellids are common in seaweed in tide pools, and the shells are found in sediments to depths of about 10 m.

Type locality: Diamond Head Beach Park, Oahu. *Holotype:* Bernice P. Bishop Museum No. 9772. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

In shape the shells resemble those of *R. caribbaea* Rehder, 1943, from Florida, but the Florida animals have a black body and white tentacles. The shells are also similar to those of *R. micra* (Finlay, 1924) from New Zealand, but in the New Zealand animals both the oral lobes and cephalic tentacles are short and club-shaped, and the animal is gray (Ponder, 1966a). Derivation of name: *longus,* Latin — long; *spira,* Latin — a coil. Refers to the comparatively long spire.

Family **Cingulopsidae**

The shells of the Cingulopsidae are minute (not more than about 5 mm in length), conical or globular, and tinted with brown. The animals have a bilobed snout, short tentacles with the eyes at the base, short caudal tentacles but no pallial tentacles and a

supra-marginal pedal gland (Fretter and Patil, 1958; Ponder, 1965b). The sexes are separate and the males aphallate. The eggs are laid singly in capsules. In the European species there is no planktonic veliger stage (Fretter and Patil, 1958). The Hawaiian representatives of the family are referred to the genus *Rufodardanula* Ponder 1965b, described for a group of New Zealand shells characterized by their minute size, reddish-brown color, and swelling above the columella.

Rufodardanula conica Kay, new species. Fig. 31 N. Length, 1 mm; diameter, 0.5 mm. *Shell:* conic; smooth; transparent, red brown. *Spire:* protoconch of one whorl not distinctly marked off; teleoconch of three convex whorls; suture impressed, false-margined. *Sculpture:* microscopic growth striae only. *Aperture:* ovate; outer lip thin; peristome thin and continuous; columella curved. *Color:* transparent, red-brown with darker brown on the columella and occasionally on the false margin of the suture.

These mollusks are occasionally found in sediments at depths of about 3 m.

Type locality: Kukuiula, Kauai, from algal mat. *Holotype:* Bernice P. Bishop Museum No. 9776. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

These shells are distinguished from those of *R. ponderi* by their more conic shape, and from those of *R. spadix* Ponder, 1965b from New Zealand by the more convex whorls. Derivation of name: *conica*, Latin — conical. Refers to the shape.

Rufodardanula ponderi Kay, new species. Fig. 33 E. Length, 1 mm; diameter, 0.5 mm. *Shell:* conic; smooth; transparent, red-brown. *Spire:* protoconch of one whorl not distinctly marked off; teleoconch of three convex whorls; suture impressed, false-margined. *Sculpture:* microscopic growth striae only. *Aperture:* ovate; outer lip thin; peristome thin and continuous; columella curved. *Color:* transparent, red-brown with darker brown on the columella and occasionally on the false margin of the suture.

These gastropods are found in the algal mat of solution benches and in sediments to depths of about 40 m.

Type locality: Mamala Bay, Oahu, from sediments at a depth of 20 m. *Holotype:* Bernice P. Bishop Museum No. 9778. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells of *R. ponderi* are distinguished from those of *R. conica* by their cylindrical shape, convex whorls, shorter last whorl, and thinner texture. The shells are similar in shape to those of *R. exaltata exaltata* (Powell, 1933, in Ponder 1965b) from New Zealand but the angle of the outer lip is more distinct in the Hawaiian shells than in the New Zealand shells. This species is named for Dr. Winston Ponder, whose contributions to the knowledge of micromollusks such as this are legion.

Superfamily ARCHITECTONACEA

Family **Architectonicidae**

Architectonicid shells superficially resemble those of the Trochidae, but the shells in architectonicids are porcelaneous, not nacreous. The spire is usually low, the whorls coiled on a wide axis, and the umbilicus is often open all the way to the apex. The surface of the shells may be relatively smooth, spirally keeled, or beaded. The shells

Figure 34.—*Philippia radiata*. Postlarva feeding on the polyps of the hermatypic coral *Porites lobata* (after Robertson and others, 1970.)

differ from those of most other prosobranchs in possessing a hyperstrophic protoconch, that is, a protoconch coiled to the left rather than the right. Because of the protoconch, and certain features of the operculum, radula and egg capsules, it has been suggested that the Architectonicidae have more in common with the pyramidellid opisthobranchs than with the prosobranchs (Risbec, 1955; Robertson, 1970b). Other workers retain the

group in the mesogastropods but distinguish them from the Cerithiacea in a separate family (Taylor and Sohl, 1962).

Three genera are represented in Hawaiian waters, *Architectonica* and *Philippia* with a solid, conical, horny operculum, and *Heliacus* with a spiral, chitinous operculum. The species of *Architectonica* and *Philippia* are sand-dwellers, found at depths of more than 3 m. The adults feed on corals (Fig. 34) (Robertson, 1970a), but juveniles of *Philippia* also feed on the sea anemone *Aiptasia* in the laboratory (J. B. Taylor, 1975). The species of *Heliacus* are associated with the sea anemones *Palythoa* and *Zoanthus* in the surge zone.

The sexes are separate and the eggs are deposited in capsules. Eggs of *Philippia radiata* have been described in the outer part of the umbilicus in a specimen from the Cook Islands (Robertson, 1970b), and juveniles have also been reported in the umbilicus of an adult specimen of *Philippia oxytropis* from Hawaii (Anon, 1962b; Robertson, 1970b). Despite these somewhat anomalous reports, the protoconchs of architectonicids are of a type associated with a planktotrophic life history. J. B. Taylor (1975) has described the four-lobed veliger larvae of *Philippia oxytropis* and *Heliacus variegatus* in the plankton of Kaneohe Bay, Oahu, and Robertson (1964) and R. Scheltema (1971) described veligers of the western Atlantic species *Philippia krebsii*. *P. krebsii* has a planktonic stage of between 74 days and three months. Robertson (1970b) concludes that *Philippia* may be unique in having a long pelagic larval stage that is both preceded and followed by umbilical brood protection.

Architectonica maxima (Philippi, 1849). Fig. 35 A-C. Height, 10 mm; diameter, 33 mm. *Shell:* depressed-turbinate; solid; with five granular spirals on the last whorl; fawn, spirally banded with brown. *Spire:* six whorls; suture channeled. *Sculpture:* four beaded spirals on each whorl, the last with an additional spiral at the periphery. *Aperture:* subcircular; operculum large, flat, paucispiral externally and with a twisted central projection internally; umbilicus wide and deep, bordered by a crenulated ridge and a narrower beaded spiral. *Color:* fawn, spirally banded with two interrupted spirals of dark brown on each whorl.

Specimens have been dredged from depths of 30 to 50 m on sandy substrates. Juveniles are occasionally found deep within the umbilicus (Anon., 1962a).

A. maxima occurs throughout the Indo-West Pacific.

Architectonica perspectiva (Linnaeus, 1758). Fig. 35 D-F. Height, 12 mm; diameter, 45 mm. *Shell:* depressed-turbinate; solid; with a single broad cord encircling the last whorl; fawn, continuous spiral bands of brown around the suture and periphery. *Spire:* five whorls; suture channeled. *Sculpture:* three rows of beaded granular spirals on the apical whorls, the middle row the widest and composed of oblique rectangular nodules; a fourth granular spiral on the last whorl. *Aperture:* subcircular, operculum large, flat, paucispiral externally and with a twisted central projection internally; base axially striate; umbilicus wide and deep, bordered by two crenulated spirals. *Color:* fawn, with two continuous or interrupted brown spirals on the apical whorls; base fawn with brown spots on the spiral sculpture.

Specimens of this species have been dredged at depths of from 30 to 50 m. As in *A. maxima*, juveniles are occasionally found in the umbilicus.

A. perspectiva occurs throughout the Indo-West Pacific.

Heliacus implexus (Mighels, 1845). Fig. 35 G, H. Height, 6 mm; diameter, 10 mm. *Shell:* depressed-turbinate; finely granular; yellow-gray. *Spire:* four whorls; suture barely indented. *Sculpture:* five spirals of obliquely set, evenly spaced granules, a single row of larger granules delimiting the suture. *Aperture:* subcircular; bordered by two peripheral keels; operculum multispiral, lamellosely fringed with conical projections externally, somewhat concave internally; base sculpture as on dorsum; umbilicus bordered by a wider spiral than remaining spirals, wide and deep. *Color:* yellow-gray or tan, with occasional dark brown spots on the sutural band.

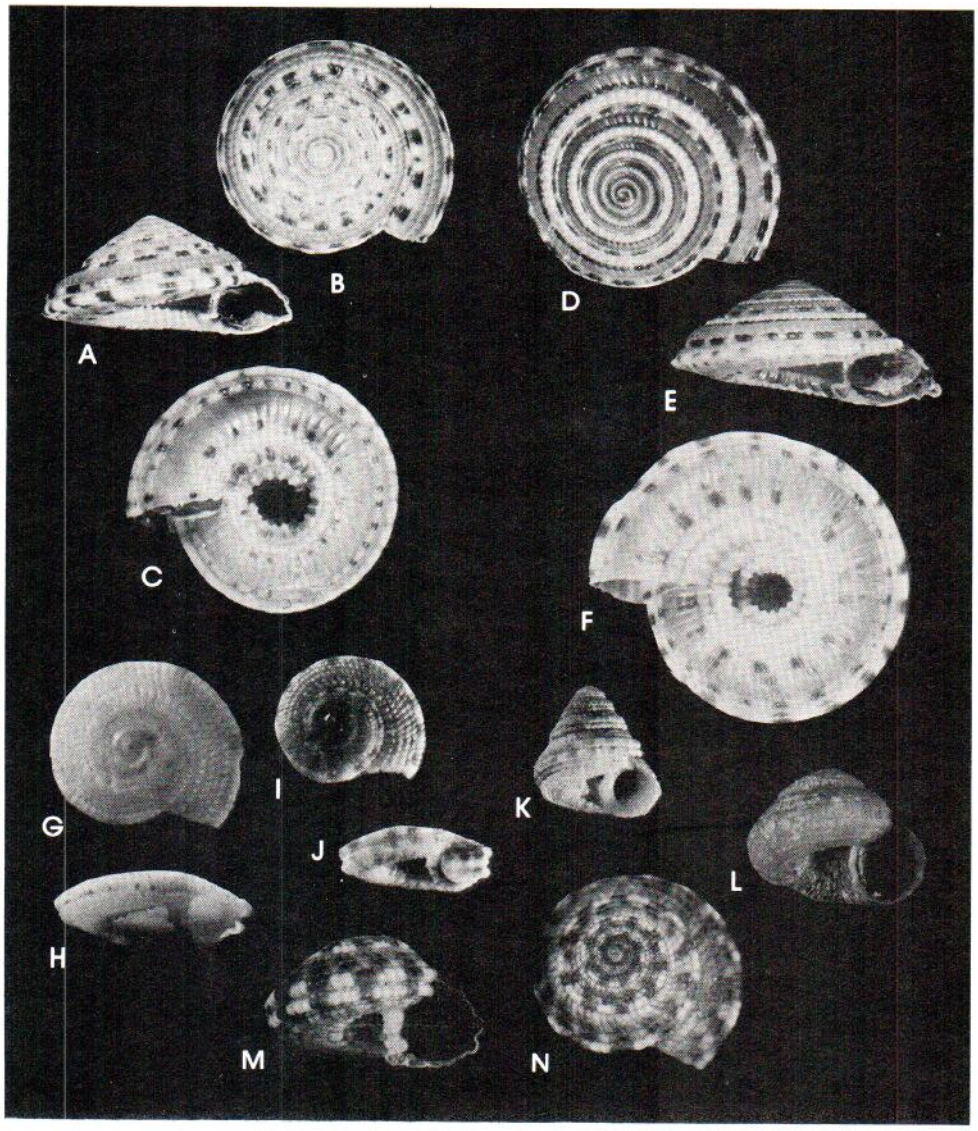


Figure 35.—**Architectonicidae.** A, B, C. *Architectonica maxima*, diameter 33 mm. D, E, F. *A. perspectiva*, diameter 45 mm. G, H. *Heliacus implexus*, diameter 5 mm. I, J. *H. sterkii*, diameter 4 mm. K. *H. trochoides*, diameter 7 mm. L. *H. mighelsi*, diameter 8 mm. M, N. *H. variegatus*, diameter 12 mm.

These architectonicids are less frequently encountered than are the other species of *Heliacus*, but occasional specimens have been found with *H. variegatus* and *H. mighelsi* in beds of the sea anemone *Palythoa;* worn shells are common in beach drift.

H. implexus was described from the Hawaiian Islands; shells have also been found at Johnston Island.

Heliacus mighelsi (Philippi, 1853). Fig. 35 L. (Synonym: *Solarium cyclostomum* Mighels, 1845, non Menke, 1830.) Height, 8 mm; diameter, 9 mm. *Shell:* turbiniform with inflated whorls; encircled by finely beaded spirals; gray-white. *Spire:* six inflated whorls; suture shouldered. *Sculpture:* minutely beaded, closely set spiral threads. *Aperture:* circular, not noticeably interrupted by spiral keels; operculum cup-shaped with a comparatively small number of flat whorls externally, subconoidal internally. *Base:* convex; sculpture as on dorsum; umbilicus circular and deep. *Color:* gray-white with occasional darker spots.

Specimens of *H. mighelsi* are commonly found with *H. variegatus* in beds of the sea anemone *Palythoa*.

H. mighelsi was described from the Hawaiian Islands.

Heliacus sterkii (Pilsbry and Vanatta, 1908). Fig. 35 I, J. (Synonym: *Torinia discoidea sterkii* Pilsbry and Vanatta, Edmondson, 1933.) Height, 2.3 mm; diameter, 4.6 mm. *Shell:* depressed; sculpture of five granular spirals on each whorl; brown with white spots on the beaded cords. *Spire:* four whorls; suture impressed. *Sculpture:* five spirals of nodular granules on each whorl, the apical and abapical spirals the largest. *Aperture:* subcircular; outer lip bordered by three keels, the bordering keels larger than the central. *Base:* umbilicus wide but narrowing toward the apex; sculpture as on dorsum. *Color:* apical whorls deep reddish brown, abapical whorls becoming gray, with white and brown spots along the peripheral beaded cords.

The habits of the living animals are unknown, but beachworn specimens are abundant in drift on southern beaches of Kauai.

Although Pilsbry and Vanatta (1908) suggested that this form represented a subspecies of *H. discoidea* (Pease, 1868d) described from the Marquesas, the Hawaiian shells differ in color and number of granular rows and are perhaps better regarded as a distinct species.

Heliacus trochoides (Deshayes, 1830). Fig. 35 K. Height, 6 mm; diameter, 8 mm. *Shell:* trochiform, with sharply angled whorls; cream with darker interrupted bands. *Spire:* four rather flat whorls; suture not distinguishable. *Sculpture:* closely set, finely beaded spirals, the periphery of each whorl marked by a spiral of larger beads. *Aperture:* subquadrate; outer lip indented by spiral sculpture. *Base:* sculpture like that of dorsum; umbilicus wide and deep, bordered by a crenulate spiral. *Color:* ashy gray with darker marks and creamy spirals around the sutures.

Specimens are occasionally found with *H. variegatus* and *H. mighelsi* in beds of the sea anemone *Palythoa* but are uncommon.

H. trochoides occurs throughout the Indo-West Pacific from Ceylon to southern Japan and the Caroline and Society islands, and is recorded from Ecuador (Robertson, 1976).

Heliacus variegatus (Gmelin, 1791). Fig. 35 M, N. (Synonym: *Torinia variegata depressa* Philippi, Edmondson, 1933.) Height, 9 mm; diameter, 12 mm. *Shell:* turbi-

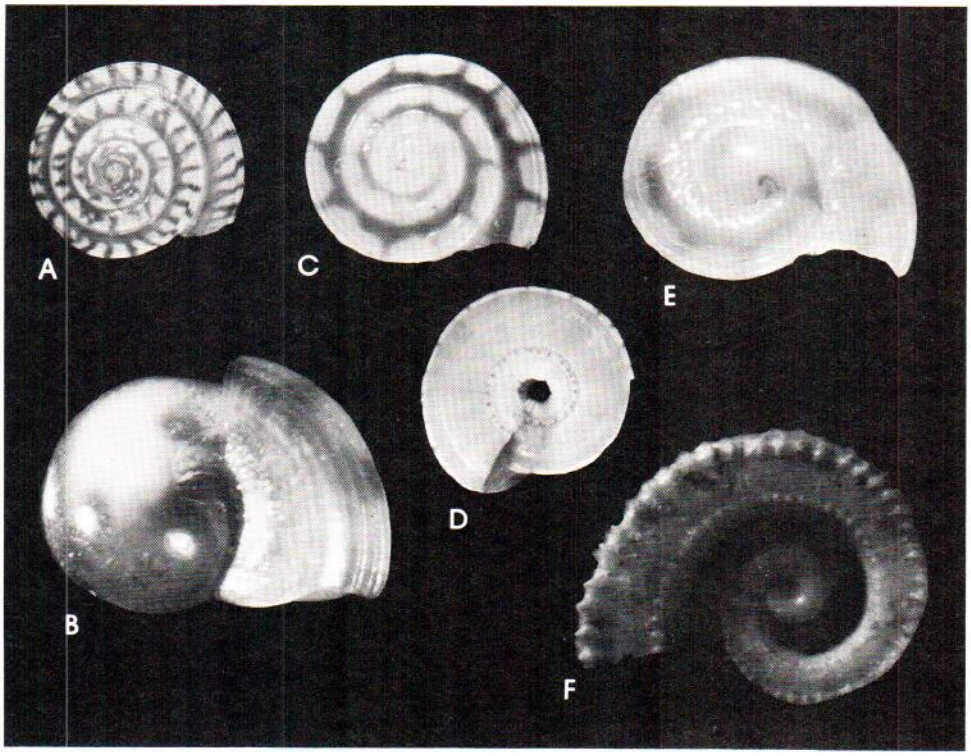


Figure 36.—**Architectonicidae.** A. *Philippia oxytropis,* diameter 14 mm. B. *P. oxytropis* protoconch and first whorl of teleoconch, diameter 2.5 mm. C, D. *P. radiata,* diameter 14 mm. E. *P. radiata* protoconch and early whorls of teleoconch, diameter 4 mm. F. *Pseudomalaxis* sp. cf. *cornuammonis,* diameter 5 mm.

nate or depressed, solid; variegated brown or black and white. *Spire:* four inflated whorls; suture barely distinguishable. *Sculpture:* four coarsely beaded cords, those marking the periphery of each whorl of larger and more convex beads. *Aperture:* subquadrate, marked by the spiral cords of the periphery. *Base:* umbilicus narrow and deep, bordered by a crenulate spiral. *Color:* brown or black, spotted with white; base around umbilicus white.

H. variegatus is the most common of the architectonicids in Hawaiian waters. The animals are associated with sea anemones of the genus *Palythoa* to which they are attached by a thin mucous thread.

This species occurs throughout the Indo-West Pacific, from the Seychelles and Ceylon to the Marquesas Islands.

Philippia oxytropis A. Adams, 1855b, Fig. 36 A, B. Height, 8 mm; diameter, 14 mm. *Shell:* depressed-turbinate; whorls angled; smooth except for spiral keels about the periphery and beaded cords around the umbilicus; white variously patterned with brown or fawn. *Spire:* protoconch slightly immersed in the teleoconch, from 1.55 to 1.75 mm in diameter (Robertson, 1970b), brown with a prominent white spot, white or brown, smooth, shiny, convex and inflated, with a varix and anal keel; teleoconch of four whorls; suture barely impressed. *Sculpture:* smooth, glossy, with one promi-

nent peripheral spiral cord bordered by one above and one below, and two periumbilical sulci with a beaded cord between. *Aperture:* circular. *Operculum:* concave, amber, semitransparent and flexible, multispirally coiled counterclockwise; with an opaque central knob internally which extends into the tissues of the foot (Robertson, 1970b). *Base:* umbilicus narrow, bordered by the cords described above. *Color:* white with patchy radiations of brown or all brown.

P. oxytropis is the more common of the two species of *Philippia*, occurring at depths of 50 to 66 m. Of more than 100 specimens of *Philippia* examined, 98 percent were identified as *P. oxytropis*. The veligers are pelagic and planktotrophic, but an adult specimen dredged alive from 50 m had in its umbilicus two juveniles (Robertson, 1970b). Juveniles, on settling, feed on the sea anemone *Aiptasia* in the laboratory (J. B. Taylor, 1975).

This architectonicid is found in the Red Sea and the subtropical western and central Pacific Ocean (New Zealand and Polynesia) (Robertson, 1970b).

Philippia radiata (Röding, 1798). Figs. 34, 36 C-E. (Synonyms: *Torinia cingulum* (Kiener) Sowerby, 1863; *Philippia hybrida* (Linnaeus) Tinker, 1952.) Height, 8 mm; diameter, 14 mm. *Shell:* as in *P. oxytropis* but distinguished by a smaller, white protoconch (1.20 to 1.45 mm in diameter) and, among the color patterns of the teleoconch, that which is white with brown subsutural bands and radial extensions (Robertson, 1970b).

These sundials are less numerous than *P. oxytropis* and occur from shallow water to depths of 50 m. The animals live buried 1 to 3.5 cm in silty sand or loose, algal-covered rubble near colonies of the coral *Porites lobata* Dana, the snails emerging at night and feeding on the polyps (Robertson and others, 1970). Metamorphosis of the veliger larvae is strongly influenced by the presence of the coral, *Porites lobata*, and growth of the teleoconch is apparently dependent on the presence of the coral (Hadfield, 1976). One animal reared in the laboratory began laying eggs at a shell diameter of 712 mm, less than three months after it had metamorphosed (Hadfield, 1976).

P. radiata ranges throughout the Indo-West Pacific from South Africa and the Red Sea to the Philippines, New Zealand, Micronesia, Polynesia, and the Marquesas (Robertson, 1970b).

Additional Record

The description of *Torinia sulcifera* Pease, 1869b, is too sketchy to permit positive identification of shells referable to that species. A shell and fragments of *Pseudomalaxis* sp. cf. *cornuammonis* (Melvill and Standen, 1903) have been dredged from depths of 200 m off Lanai and Oahu (Fig. 36 F). *P. cornuammonis* was described from shells dredged from 156 fathoms in the Gulf of Oman.

Superfamily CERITHIACEA

This superfamily includes a very large group of marine and freshwater snails, typically with high-spired shells with a siphonal notch, but including also the sedentary coiled shells of the Vermetidae and the tusklike shells of *Caecum*. Cerithiaceans are

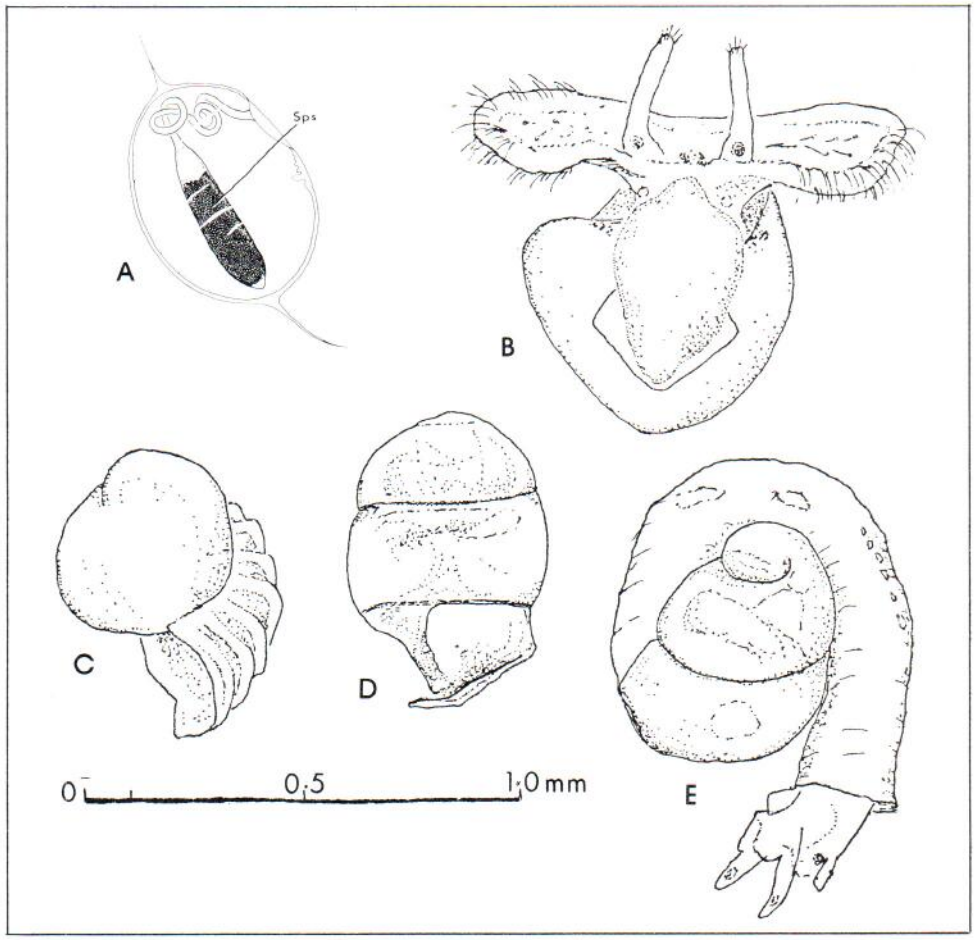


Figure 37.—Vermetid life history. A. Spermatophore of a Californian vermetid. B. *Dendropoma psarocephala*, ventral view, premetamorphic veliger. C. *D. platypus*, premetamorphic protoconch. D. *Serpulorbis variabilis*, premetamorphic protoconch. E. *Petaloconchus keenae*, post-metamorphic protoconch and initial teleoconch. (A from Hadfield, 1966; B-E from J. B. Taylor, 1975.)

especially characteristic of the tropics and subtropics where they often occur in great numbers. Most cerithiaceans are herbivorous, grazing on algae or algal film, but the Triphoridae and Cerithiopsidae are specialized sponge feeders with a long proboscis which may be inserted into the sponge. Except in *Caecum*, male cerithiaceans lack a penis, and sperm are transferred by way of open reproductive ducts by special types of spermatozoa (Fig. 37 A).

Family **Vermetidae**

Vermetids are recognized by their coiled, wormlike shells which are cemented to hard substrates. The shells of gregarious species may be so numerous as to form vermetid reefs which have been described in the Cape Verde Islands (Crossland, 1905), along the Mediterranean shore of Israel (Safriel, 1966), and along the coastline

of Brazil (Kempf and Laboriel, 1968). In Hawaii one species, *Dendropoma gregaria,* which as its name implies is gregarious, is an intertidal zone former, veneering solution benches and boulders with a mat of shell several centimeters in thickness. Densities of *D. gregaria* on a bench at Diamond Head, Oahu, were estimated at 60,000/m^2 (Hadfield and others, 1972). Four solitary species are also common in the intertidal; their coiled shells may be more than 40 mm in diameter. At least three small species of *Dendropoma* are associated with subtidal coral communities where they seem to be almost exclusively associated with coralline algal substrates.

Vermetids, because of their sessile habit, feed either by mucous net or by ctenidial cilia. In *Dendropoma* the pedal tentacles spin small droplets of mucus into fine threads which attach to the substrate near the aperture and become laden with diatoms and detritus. The food-laden threads are then rasped by the radula and jaws and ingested. Ciliary feeding involves the production of an inhalant current in the mantle cavity by the ctenidia; plankton and detritus are removed from the water current by mucus produced in the mantle cavity and the food-laden bolus of mucus is ingested.

Despite the sessile habit, sexes are separate and fertilization is internal, by large eupyrene sperm which enter the mantle cavity of the females. The eggs are brooded in capsules either in the mantle cavity or attached to the shell from which they hang suspended in the mantle cavity through a cleft in the pallial wall of the female. Hawaiian vermetids appear to reproduce continuously throughout the year and most produce small, hatching juveniles rather than swimming veligers.

The four genera recognized in Hawaiian waters may be keyed as follows:

1. Operculum present 2
   Operculum absent; foot large, brightly colored ..... *Serpulorbis*
2. Operculum small, concave; tubes tending to be loosely coiled and rising above the substrate 3
   Operculum elaborate, filling the tube and with an axial mamilla; shell entrenched or partially embedded in the substrate ..... *Dendropoma*
3. Shell with an internal lamella ..... *Petaloconchus*
   Shell without an internal lamella ..... *Vermetus*

Dendropoma gregaria Hadfield and Kay, 1972. Fig. 38. *Shell:* small (maximum apertural diameter 3 mm); tubes forming compact, continuous mats, each individual tube fitting into a channel eroded into the calcareous mass of the other shells. Surface scaly owing to numerous raised concentric lamellae. Exterior deep purple-black; interior dark and glossy. *Operculum:* variable in shape, from a flattened, shiny, deep red-brown disk with concentric rings to a highly domed, tough, horny cone; inner surface with a prominent mamilla. *Animal:* mesopodial pad brilliant lavender pink or, occasionally, light-yellow. Mantle black except for the border which is flecked with white. Mantle margin entire in both sexes.

D. gregaria forms dense masses more than five cm in thickness on benches such as those at Maili Point and Diamond Head, Oahu. The mat, which coats boulders, may extend more than 13 cm from the vertical surface. These vermetids appear to be restricted to a rather narrow zone about, or slightly below, the zero-tide level. They are preyed on by the thaidids *Morula granulata* and *M. uva.*

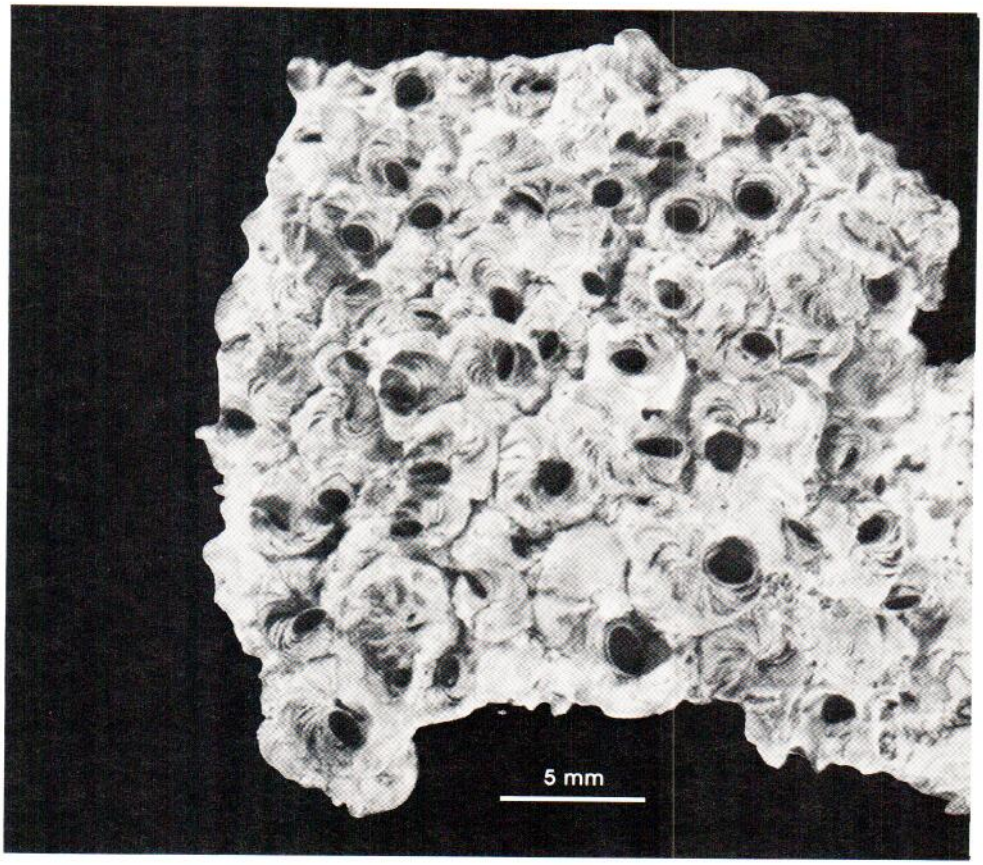


Figure 38.—*Dendropoma gregaria*. Mass of adult tubes with 59 tube apertures in an area of less than 10 cm^2. (From Hadfield and others, 1972.)

D. gregaria was described from the Hawaiian Islands, and is also common in the Marshall Islands and at Fanning Atoll in the Line Islands.

Dendropoma meroclista Hadfield and Kay, 1972. Fig. 39 A. *Shell:* small (maximum tube diameter 1.5 mm); tube deeply embedded in the substrate and usually overgrown with calcareous algae. Aperture almost completely closed by a convex dome of shell, leaving only a narrow slit. Sculpture of irregular axial ribs and fine concentric striae on exposed portions of the shell. Exterior typically dark purple; interior white, sometimes stained with green. *Operculum:* mushroom-shaped, fitting under the convex dome of the aperture; nacreous white. Pedal surface planar except for the projecting mamilla. *Animal:* head, foot, and cephalic tentacles dark purple or black with a few superficial markings; pedal tentacles with a white spot near the tips. Mantle margin split in the females.

These small vermetids are solitary but settle within one or two millimeters of each other, on coralline algal-encrusted coral of fringing and patch reefs such as at Waikiki and in Kaneohe Bay, Oahu. The bilobed veliger larvae are planktonic for a few hours, or at most a few days; metamorphosis occurs when one and one-half to one and two-thirds whorls are complete (J. B. Taylor, 1975).

Figure 39.—**Vermetidae.** A. *Dendropoma meroclista* showing the diagnostic constriction of the shell aperture. B. *D. platypus*. C. *D. rhyssoconcha* with characteristic frilled lamellae. D. *D. psarocephala*, dark-colored shell with concentric lamellae. (From Hadfield and others, 1972.)

D. meroclista was described from the Hawaiian Islands and is also common on the seaward reef flat at Enewetak, Marshall Islands.

Dendropoma platypus Morch, 1861. Figs. 37 C; 39 B. *Shell:* of medium size (diameter of whorls up to 20 mm; maximum apertural diameter, 7 mm); tube usually tightly coiled on itself and embedded in coral or on shells. Aperture circular to slightly ovoid. Upper surface with wavy axial riblets and occasionally with a keel on the dorsal surface of the coils. Exterior porcelain white or mottled with dark brown, green and/or purple. *Operculum:* shaped like an inverted cone with the apex a central red spot marking the mamilla on the pedal surface and with brown spirals; remainder of operculum clear and transparent but often encrusted with algae in life. *Animal:* black with superficial markings of yellow and white speckles; rolled edge of mantle yellow alternating with black. Mantle margin entire in both sexes.

These vermetids are solitary, found usually completely embedded in submerged substrates of coral or shell, or coiled above coral in quiet waters. They occur from the intertidal to depths of 14 m off Oahu. These vermetids hatch both as functional juveniles and as planktonic larvae (J. B. Taylor, 1975).

D. platypus was described from the Hawaiian Islands.

Dendropoma psarocephala Hadfield and Kay, 1972. Figs. 37 B; 39 D. *Shell:* small (maximum tube diameter 2.5 mm); tube deposited in a vertical helical coil but often conforming to the substrate. Aperture circular, flush with the substrate. With irregular axial riblets which may be developed as laminae on the inner surface of the shell. Dark purple. *Operculum:* convex, thick, ranging from buttonlike to domed in shape; composed of concentric layers of dark red, chitinous material; pedal surface rimmed by a dark glossy red annulus edged with white and with a white mamilla. *Animal:* head and foot black with superficial white spots; rolled edge of mantle collar with tiny black pigment spots. Mantle margin entire in both sexes.

These small vermetids are solitary but settle within one to two millimeters of each other on coralline-algal encrusted coral on fringing and patch reefs at Waikiki and in Kaneohe Bay, Oahu.

D. psarocephala was described from the Hawaiian Islands.

Dendropoma rhyssoconcha Hadfield and Kay, 1972. Fig. 39 C. *Shell:* small (maximum tube diameter 3.5 mm); tube deposited in a vertical helix but often following the contours of the substrate and overgrown with calcareous algae so that only the aperture is exposed. Aperture circular, almost flush with the substrate. Sculpture of irregular axial ribs on the early teleoconch, becoming scaly axial lamellae which are fluted where crossed by spiral ribs on older portions. Orange-brown, pink or dark purple. *Operculum:* shaped like an inverted cone; chitinous, translucent and colorless except for a dark red central spot marking the mamilla on the pedal surface. *Animal:* head, foot, mantle and tentacles black, dark green or brown-tan spotted with white or cream-yellow; rolled edge of the mantle collar striped by alternating light and dark colors; foot encircling the operculum red. Mantle margin entire in both sexes.

These small vermetids are solitary but settle within 1 to 2 mm of each other on coralline algal-encrusted coral on fringing and patch reefs in Kaneohe Bay and at Waikiki, Oahu. The operculum is frequently overgrown with calcareous and noncalcareous algae, making the field identification difficult.

D. rhyssoconcha was described from the Hawaiian Islands.

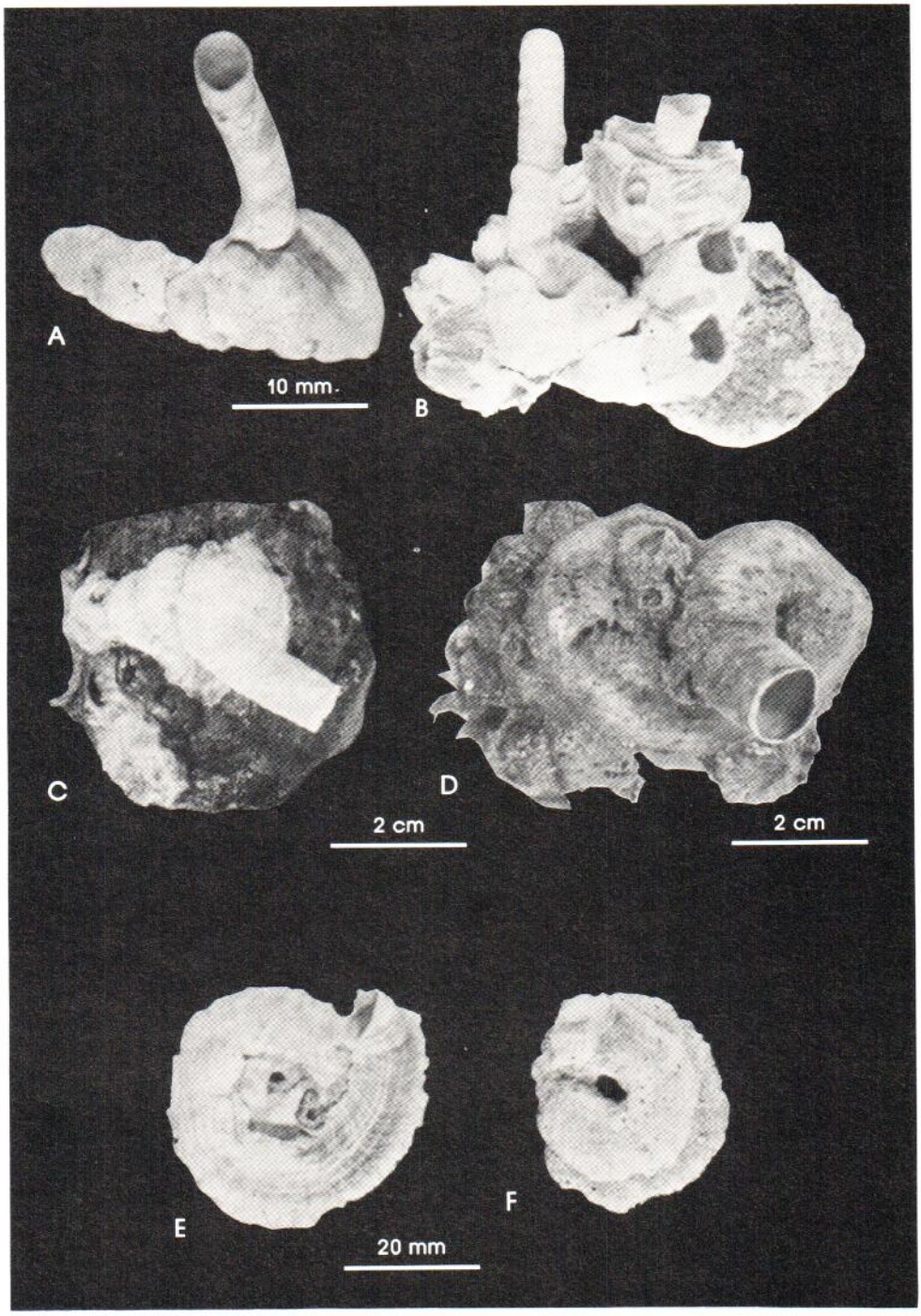


Figure 40.—**Vermetidae.** A. *Petaloconchus keenae,* coiled adult shell on smooth surface. B. *P. keenae,* irregularly coiled adult shell. C. *Vermetus alii,* cleaned shell. D. *V. alii,* typical dark shell of living adult. E, F. *Serpulorbis variabilis,* left shell with partly closed coil, right shell with more typical closed coil. (From Hadfield and others, 1972.)

Petaloconchus keenae Hadfield and Kay, 1972. Figs. 37 E; 40 A, B. *Shell:* of medium size (diameter of whorls up to 10 mm; apertural diameter, 5 mm); early whorls of teleoconch forming a conical coil on the substratum, later whorls emergent and projecting several centimeters above the substratum. Aperture circular. Sculpture of axial ribs crossed by obsolete striae. Cream, red-brown, or dark purple, with newly deposited shell of older individual pale lavender. *Operculum:* slightly concave, with a thickened and raised black center and a small mamilla on the pedal surface; chitinous, thin and transparent; about one-third the diameter of the aperture. *Animal:* head, foot, tentacles and mantle handsomely pigmented dark purple to rosy brown, sprinkled with white dots and with yellow on the rolled edges of the mantle. Mantle margin split in the females.

This is the most common and ubiquitous vermetid in the Hawaiian Islands, occurring intertidally and subtidally wherever there is suitable substrate. It is the dominant species on coralline algal-covered surfaces of patch reefs in Kaneohe Bay, Oahu, and forms fingerlike protuberances in coral in subtidal coral communities.

P. keenae was described from the Hawaiian Islands, and also occurs in the Marshall Islands.

Serpulorbis variabilis Hadfield and Kay, 1972. Figs. 6 D; 37 D; 40 E, F. *Shell:* large (diameter of whorls up to 40 mm; apertural diameter 7 to 9 mm); tube deposited in a single, flat, planorboid coil, hollow in the center or filled by an earlier whorl. Aperture circular when tubes are raised from substrate or with adherent corners when completely attached to substrate. Sculpture of heavy axial ribbing running the length of the tube, with about four ribs; spiral ribs crossing the axial ribs heavy to fine. Externally white or white-tan, sometimes mottled with irregular darker streaks; interior nacreous white and light brown. Nonoperculate. *Animal:* color variable — head, foot, cephalic and pedal tentacles and mantle usually mottled orange, white, and yellow, or bright red or brown with white and yellow; some individuals predominantly brown, others bright orange. Metapodial plug translucent white with opaque white and brown spots, the spots often rising as distinct tubercles; foot margined with alternating brown and white spots.

S. variabilis is a commonly occurring vermetid on intertidal benches on Kauai, Oahu, Maui and Hawaii, at the seaward edge of tide pools, and subtidally to depths of 14 m. These vermetids often form a narrow band on boulder surfaces at the 0 tide level. Juveniles hatch as small planktonic veligers, and the larvae may spend several weeks in the plankton (Hadfield and others, 1972).

The character and texture of the shell vary with habitat: animals from pools and crevices have thick shells heavily encrusted with coralline algae, terminating in raised tubes and circular apertures. Animals found on intertidal benches have shells which are almost completely attached, and the aperture is usually drawn out at the corners. The external surface of the shell is frequently obscured by a heavy layer of adherent sand grains.

S. variabilis was described from the Hawaiian Islands and is common in the Marshall Islands, and at Fanning Island, Line Islands. At Kwajalein, Marshall Islands, it forms a zone approximately 3 m wide on the windward ocean reefs.

Vermetus alii Hadfield and Kay, 1972. Fig. 40 C, D. *Shell:* of medium to large size (diameter of whorls up to 35 mm; maximum apertural diameter, 8 mm); tube in

loose coils which may be planorboid but with the distal end often rising several centimeters above the substrate. Aperture circular. Sculpture on earlier whorls of strong axial ribs intersecting and producing a regularly cancellate pattern; later parts of the shell with fine, raised threads. Exterior white with brown streaks; interior white smudged with brown. *Operculum:* concave with a large, flat central disk attached to the foot; peripheral portions transparent amber with acute spiral lamellae. *Animal:* head, foot, tentacles and mantle purple-red shading to rose at the edges and toward the neck, spotted with white; posteroventral portion of foot brown-yellow; edge of mantle collar yellow, grading from dark purple to rose posteriorly. Mantle margin entire in both sexes.

This is the largest species of the Hawaiian vermetids occurring intertidally and subtidally cemented to coral heads and concrete sea walls in bays such as Kaneohe Bay and Pearl Harbor, Oahu. The shell is usually overgrown with algae which obscure the color and sculpture of the teleoconch. The veliger larvae are planktonic (J. B. Taylor, 1975).

V. alii was described from the Hawaiian Islands.

Additional Record

Dendropoma maxima Sowerby, 1825, the very large vermetid which is common throughout the tropical Pacific is recorded from Pleistocene fossils (Kosuge, 1969).

Family **Caecidae**

The minute, curved shells of the members of this family are unlike those of any other mollusks, and they are sometimes called the false tooth shells because of their tubular forms. Caecids start out with a spiral shell (Fig. 42) but then grow without spiraling as a slightly curved tube. Eventually the tube breaks off, the broken end is closed with a calcareous septum, and the animals lead a benthic existence in the algal-sand mat of tide pools or in sediments to depths of several hundred meters (Fig. 41). The aperture of the adult shell is circular and there is a horny operculum.

Caecum arcuatum de Folin, 1867. Fig. 42 C. Length, 2.75 mm; diameter, 0.5 mm. *Shell:* tubular, noticeably curved and tapering toward the apical end; ringed by about 20 strong, regular, slightly keeled transverse rings separated by interspaces of about equal breadth and depth; aperture slightly flared and with two or three smaller rings; septum flat with a feeble bulge in the center. *Color:* yellow-brown, often white toward the apical end.

C. arcuatum is common in tide pools and on solution benches and is occasionally found in sediments to depths of 20 m.

This species was described from Tonga as a variety of *C. sepimentum,* but is so consistently distinct from *C. sepimentum* in size, shape, and color that it is recognized as a distinct species.

Caecum sepimentum de Folin, 1867. Figs. 41, 42 B. Length, 2.0 mm; diameter, 0.5 mm. *Shell:* tubular, very slightly curved and tapering; ringed by 16 or 17 strong, regular, rounded transverse rings separated by interspaces of equal breadth and depth; aperture with two or three smaller rings; septum flat. *Color:* red-brown.

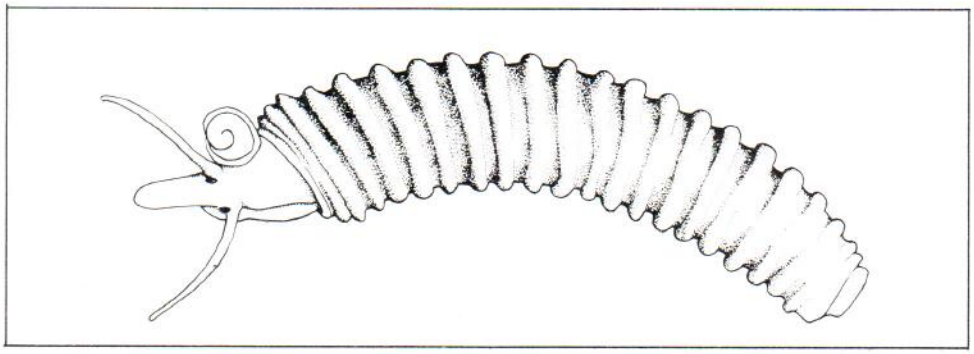


Figure 41.—*Caecum sepimentum*. Living animal.

This species is ubiquitous, abundant in the sand-algal mat of tide pools and benches and in sediments to depths of 80 m.

C. sepimentum was described from Mauritius and also occurs in Tahiti and Tonga (de Folin, 1879), and the Tuamotus (Dautzenberg and Bouge, 1933). *C. lilianum* Hedley, 1903, from New South Wales, Australia, may be a synonym.

Caecum vertebrale Hedley, 1899. Fig. 42 D. Length, 2.0 mm; diameter, 0.5 mm. *Shell:* tubular, slightly curved; with 22 to 25 moderately strong, rounded transverse rings separated by interspaces of about equal breadth and depth; aperture with a single larger ring; septum strongly convex. *Color:* light brown.

This species is rather infrequently found, at depths of about 30 m.

C. vertebrale was described from Funafuti and has been reported from Pleistocene drill holes in Tonga and at Enewetak, Marshall Islands (Ladd, 1972).

Caecum (Brochina) sp. cf. *glabella* A. Adams, 1868. Fig. 42 G. Length, 2.25 mm; diameter, 0.45 mm. *Shell:* slender, moderately arcuate; sculpture of extremely fine, close, axial threads; aperture circular; septum prominently rounded. *Color:* posterior end opaque white, anterior gradually fading to translucent white, middle olivaceous.

These caecids are uncommon, found in sand at depths of from 1 m to 42 m.

C. glabella was described from Tanabe Bay, Wakayama Prefecture, Japan.

Caecum (Fartulum) exile (De Folin, 1875). Fig. 42 A. Length, 2.25 mm; diameter, 0.45 mm. *Shell:* tubular, very slightly curved and tapering; microscopic, transverse rings especially near the aperture; shell expanding toward the aperture and contracting just under the slightly flared lip; thin and vitreous. Apical plug cap-shaped.

Shells are occasionally found in sediments from reefs and shallow pools and to depths of 28 m.

This species was described from Tonga.

Caecum (Micranellum) oahuense (Pilsbry, 1921). Fig. 42 E. Length, 2 mm; diameter, 0.4 mm. *Shell:* tubular, very slightly curved and tapering; ringed by about 40 closely set, rounded rings, their interspaces narrower than the rings; aperture slightly convex with two or three finer rings; septum convex. *Color:* anterior white, remainder yellow brown.

This species is uncommon, found occasionally in sediments in tide pools and to depths of 8 m.

C. oahuense was described from the Hawaiian Islands. The shells are distinguished from those of *C. vertebrale* Hedley, 1899, from Funafuti, which Hedley compared with fragments illustrated by Watson (1886) from Honolulu, by the rounder and more numerous rings.

Meioceras sandwichensis de Folin, 1886. Fig. 42 F. Length, 2 mm; diameter, 0.5 mm. *Shell:* arcuate, arched on one side, nearly straight on the other; circular in cross section. *Sculpture* of fine growth rings. Aperture slightly contracted, oblique. Septum small. *Color:* white.

These caecids are apparently quite rare, but shells have been found in sediments at depths of from 1 to 30 meters.

M. sandwichensis was described from the Hawaiian Islands. The shells resemble those of *M. legumen* Hedley, 1899, from Funafuti, but in that species the septum is more pointed than it is in the Hawaiian shells.

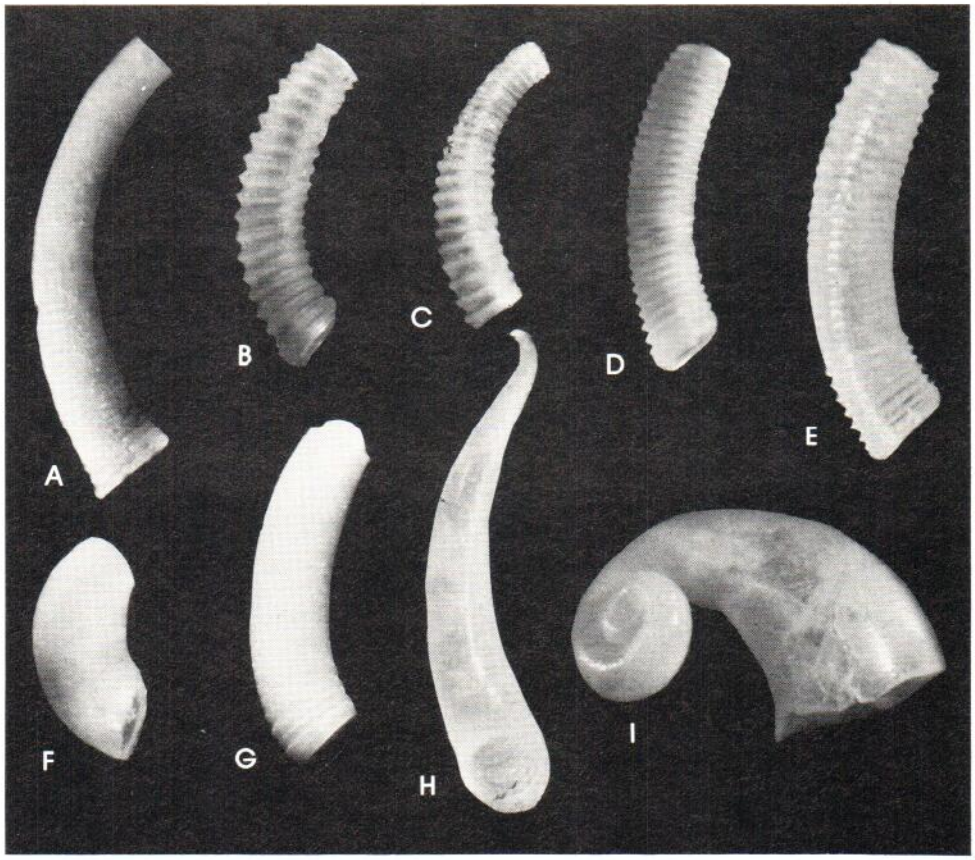


Figure 42.—**Caecidae.** A. *Caecum exile*, length 2.25 mm. B. *C. sepimentum*, length 2.0 mm. C. *C. arcuatum*, length 2.75 mm. D. *C. vertebrale*, length 2.5 mm. E. *C. oahuense*, length 2.0 mm. F. *Meioceras sandwichensis*, length 1.5 mm. G. *Caecum* sp. cf. *glabella*, length 2.25 mm. H. *Strebloceras subannulatum*, length 3 mm. I. Juvenile shell, *Caecum* sp., 1.5 mm.

Strebloceras subannulatum de Folin, 1879. Fig. 42 H. Length, 3 mm; diameter of anterior end, 0.5 mm. *Shell:* cornucopialike, thin, vitreous, translucent, and glossy; the apical terminus of two and one-half whorls at the side of the shell, the tube increasing in breadth and curving in two planes; aperture oblique.

These caecids are found in sediments at depths of from 28 to 80 m.

S. subannulatum was described from the Hawaiian Islands.

Family **Planaxidae**

These gastropods are sometimes called "cluster winks" because of their habit of clustering together in large numbers on rocky shores. The shells are of medium size, thick, conic-ovate, and often covered with a strong periostracum. The aperture is oval, lirate internally, and there is a narrow sinus. The operculum is horny. Although the shape of the shell is similar to that in the Littorinidae, planaxids are distinguished by a slight notch in the anterior end of the aperture, thicker and heavier shells, and a fibrous periostracum.

Reproduction in planaxids is parthenogenetic. There are no males and there is an adventitious brood pouch in the neck region, with the opening on the right side of the neck (Morrison, 1954). All planaxids for which the larval life is known are reported to be planktonic.

Planaxis labiosa A. Adams, 1853b. Fig. 43 B, C. (Synonyms: *Planaxis plumbea* Pease, 1861c; *P. striatulus* Philippi, Martens and Langkavel, 1871; *P. lineatus* da Costa var. *labiosus*, Tryon, 1887.) Length, 13 mm; diameter, 7 mm. *Shell:* conic-turbinate, solid; spirally banded with brown and white. *Spire:* protoconch of three or four spirally keeled, narrowly conical whorls; teleoconch of six convex whorls, the last whorl more than two-thirds the length of the shell; suture distinct. *Sculpture:* apical whorls with distinct spiral cords, later whorls also with spiral cords or smooth. *Aperture:* ovate; lirate within; apical channel expanded and curving upward. *Color:* variable — usually spirally banded with brown and white but sometimes all white or all brown; periostracum dark brown, velvety.

These gastropods are gregarious, abundant under rocks along shorelines where the water is brackish. Empty shells are commonly occupied by hermit crabs.

P. labiosa was described from the Hawaiian Islands but also occurs elsewhere in the tropical Pacific. The Hawaiian shells are distinguished from those of *P. lineatus* (da Costa, 1776) from southeast Florida, Brazil, and Bermuda by their larger size and longer apertures in proportion to their length.

Planaxis suturalis E. A. Smith, 1872. Fig. 43 D. Length, 8 mm; diameter, 3.5 mm. *Shell:* conic-turbinate, solid; with spiral grooves; white. *Spire:* protoconch of three spirally keeled, conical, brown whorls; teleoconch of six convex whorls, the last whorl more than two-thirds the height of the spire; suture distinct. *Sculpture:* spiral sculpture of sharp, deep grooves with wider, rather flat, interspaces. *Aperture:* ovate; lirate within. *Color:* white.

These planaxids are known only from shells found at depths of from 10 to 30 m.

P. suturalis was described from "the China Seas." The shells are consistently distinct from those of *P. labiosa* in their white color and sharply defined grooves.

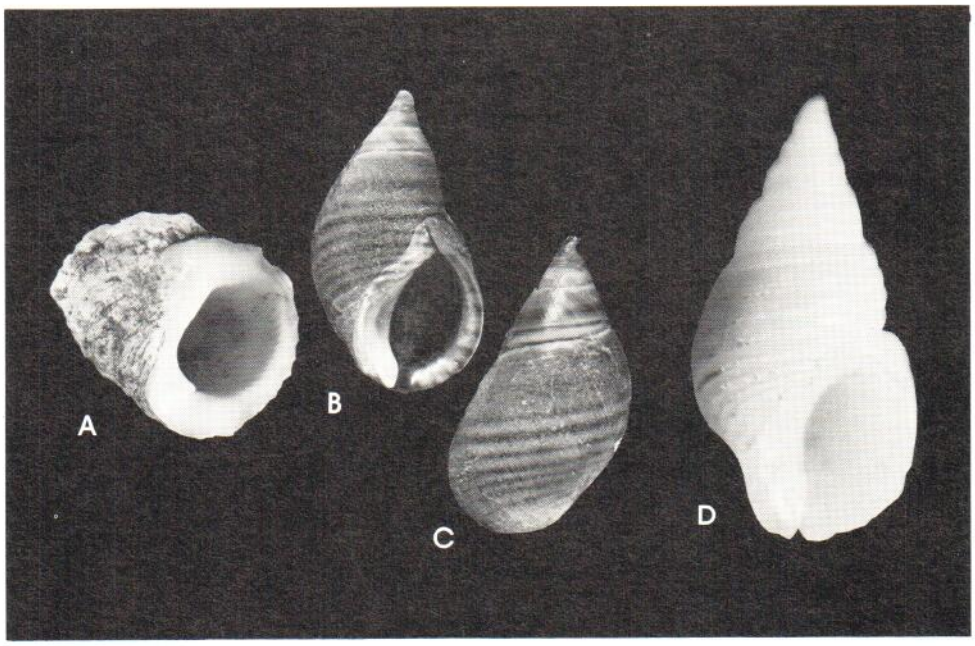


Figure 43.—A. *Modulus tectum*, diameter 20 mm. B, C. *Planaxis labiosa*, length 12 mm. D. *P. suturalis*, length 8 mm.

Additional Records

Six planaxid names have been recorded from the Hawaiian Islands, but none represents species known to live in these waters. *P. hanleyi* E. A. Smith, 1872, and *P. similis* E. A. Smith, 1872, both described from the Hawaiian Islands, are synonyms of *P. niger* Quoy and Gaimard, 1834, which occurs from the Indian Ocean to Central Polynesia, as does *P. abbreviata* Pease, 1865b, which was recorded from Hawaii by Sowerby (1874). *P. sulcatus* (Born, 1780), recorded from Hawaii by Melvill and Standen (1898), is widely distributed throughout the Indo-West Pacific but is not known to occur in Hawaii.

Family **Modulidae**

There is a single genus in this family, *Modulus*, represented by only a few species in warm, tropical seas. In shape the shells resemble turban shells, but they are entirely porcelaneous and there is a projecting toothlike structure at the base of the columella. The aperture is lirate and the operculum is chitinous and multispiral.

Modulus tectum (Gmelin, 1791). Fig. 43A. Length, 18mm; diameter, 20 mm. *Shell:* turbinate, solid; with axial ribbing; cream-colored. *Spire:* last whorl large, bulbous but angular; apical whorls flat; suture impressed. *Sculpture:* weak spiral ribs and stronger axial ribs. *Aperture:* quadrangular, lirate, outer lip thin; a projecting tooth at the base of the columella; operculum circular and transparent. *Color:* white

with occasional brown splashes. *Animal:* foot green; mantle edged with green and brown; proboscis dark green, tentacles pale green.

These mollusks are common in sand or algal-sand mats in tide pools and on benches, and have been dredged from depths of 100 m. The shells are often covered with heavy growths of algae.

M. tectum occurs throughout the Indo-West Pacific.

Family **Dialidae**

This group of cerithiaceans is ill-defined and little is known of the habits or anatomy of the animals. The species reported here are included in the family more as a matter of convenience than as indicating relationships. They have in common small size (from 2 to about 7 mm in length) and a complete aperture which distinguishes them from *Bittium* and other members of the Cerithiidae. Differences in protoconchs may, however, belie different phylogenies.

Dialids are a major component of micromolluscan assemblages of shallow reef flats and lagoons elsewhere in the Pacific. *Diala flammea* (Pease, 1868b) is abundant in the lagoon at Fanning Island and at Canton Island (Kay and Switzer, 1974; Kay, 1976); at Fanning these gastropods are associated with algae such as *Hypnea* and *Polysiphonia*. *Finella pupoides* is a characteristic component of the sediments of the turbid lagoon at Fanning (Kay and Switzer, 1974), and *Finella* and *Scaliola* spp. are abundant in the turbid lagoon sediments at Canton (Kay, 1976). In Hawaiian waters the dialids are, with one exception, subtidal, abundant at depths of more than 3 m where they appear to replace the Cerithiidae and Rissoidae as the dominant components of micromolluscan assemblages in deep water.

The six dialid genera recognized here may be keyed as follows:

1. Shell smooth, with spiral threads or beaded spiral cords 2
   Shell agglutinated with sand grains ..... *Scaliola*
2. Shell smooth 3
   Shell with nodular or granular spiral cords 4
   Shell with fine spiral threads ..... *Finella*
3. Shell conical, brown or brown flecked with white ..... *Diala*
   Shell with styliform apex; transparent, white ..... *Styliferina*
4. White, with sharply nodular sculpture ..... *Argyropeza*
   Brown or cream with rounded beadlike sculpture ..... *Cerithidium*

Argyropeza leucocephala (Watson, 1886). Fig. 44 C. Length, 3.5 mm; diameter, 1 mm. *Shell:* conical, high-spired; with prominently beaded spirals; glistening, cream white. *Spire:* protoconch of two and one-half spirally threaded, brown whorls; teleoconch of seven convex whorls; suture wide, distinct, almost constricted. *Sculpture:* about nine rather prominent axial ribs crossed by strong spiral threads (on the apical whorls two spirals, on last whorl three) forming sharp nodules at their junctions; axial ribs stopping on the periphery of the last whorl, remainder of whorl and base with two or three subspinose spiral threads. *Aperture:* ovate; outer lip sharp. *Color:* translucent white when alive; opaque, glistening, cream when worn.

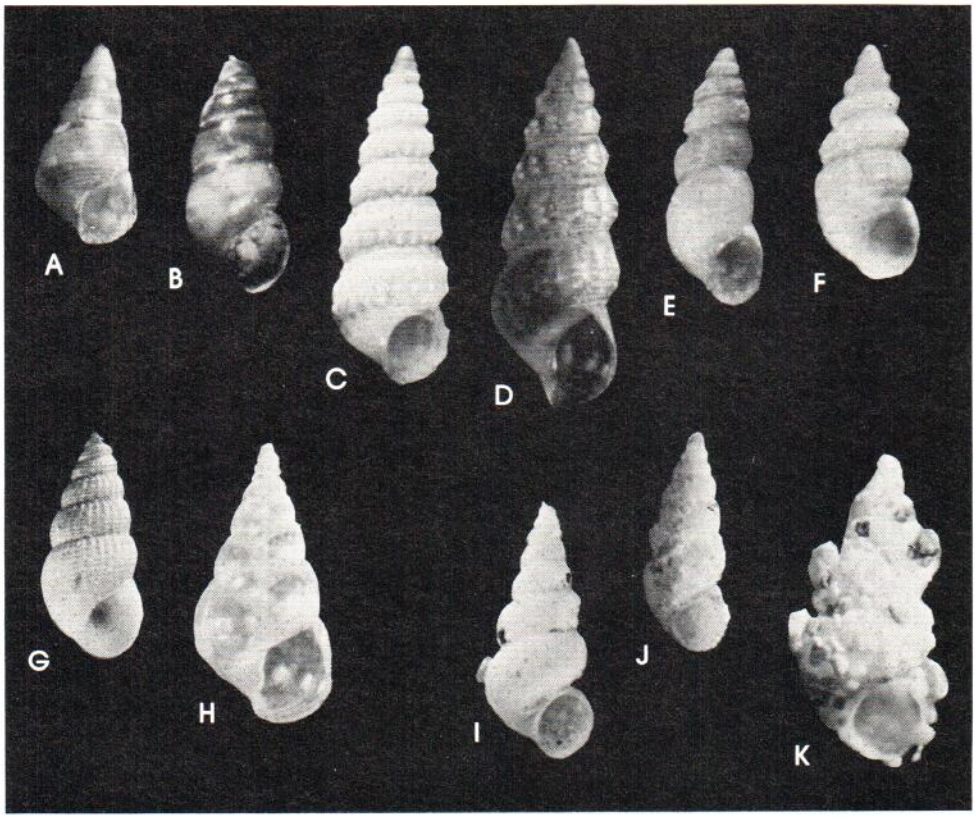


Figure 44.—**Dialidae.** A. *Diala varia*, length 2 mm. B. *D. scopulorum*, length 3 mm. C. *Argyropeza leucocephala*, length 3.5 mm. D. *Cerithidium diplax*, length 2 mm. E, F. *C. perparvulum*, length 2 mm. G. *Finella pupoides*, length 3 mm. H. *Styliferina goniochila*, length 3 mm. I. *Scaliola bella*, length 4 mm. J. *Scaliola glareosa*, length 3 mm. K. *S. gracilis*, length 3 mm.

These mollusks are common at depths of 200 to 250 m.

A. leucocephala was described from the Hawaiian Islands.

All described species of *Argyropeza* come from depths of from 200 to 400 m. The Hawaiian shells are distinguished from the type species in the genus, *A. divina* Melvill and Standen 1901 from the Persian Gulf, by more convex whorls and from *A. schepmani* Melvill and Standen, 1901 and *A. divina* by the less spinose sculpture. In the shells of *A. izekiana* Kuroda, 1949, from Japan, the apical nodular spiral thread is closer to the suture than it is in the Hawaiian shells.

Cerithidium diplax (Watson, 1886). Fig. 44 D. Length, 2 mm; diameter, 1 mm. *Shell:* conic-elongate, slender; with two beaded spiral threads; transparent white or cream. *Spire:* apex attenuate; protoconch of one and one-half smooth whorls; teleoconch of six convex, turreted whorls; suture broad, shallow, impressed. *Sculpture:* the two apical whorls spirally striate, the others bicarinate with a larger and a smaller beaded spiral thread just below the periphery of each whorl. *Aperture:* subcircular; outer lip thin. *Color:* transparent, shining white or cream.

Shells are found in sediments at depths of about 13 m and become very common in deeper waters at depths to 60 m. There is a planktonic veliger larva.

C. diplax was described from Amboina and has also been recorded from the Cocos-Keeling Islands (Maes, 1967).

Cerithidium perparvulum (Watson, 1886). Fig. 44 E, F. Length, 2 mm; diameter, 0.75 mm. *Shell:* conic-elongate, turreted; with finely beaded axial ribs and spiral threads; white to brown. *Spire:* protoconch of two smooth, white or brown mamillate whorls; teleoconch of five convex, slightly turreted whorls; suture impressed. *Sculpture:* straight axial ribs with interspaces of about equal diameter and spiral threads rendering the ribs nodulose where they cross. *Aperture:* subcircular; outer lip thin, smooth; columella straight; siphonal canal abruptly short. *Color:* variable — white, cream, yellow, or brown.

These shells are occasionally found in tide pools and on fringing reefs but are abundant at depths of 13 to 50 m where they form the dominant element in the micromolluscan assemblages, comprising up to 25 percent of the small gastropods found. The planktonic veliger larvae are among the most common cerithiaceans in the Hawaiian plankton. These dialids deposit their first egg masses when the shell has nine or ten whorls; when food is plentiful in the laboratory they pass from newly settled juveniles to reproductive adults in less than one month (J. B. Taylor, 1975).

C. perparvulum was described from the Torres Straits and Cape York, Australia, Tonga, and Honolulu.

Diala scopulorum (Watson, 1886). Fig. 44 B. Length, 3 mm; diameter, 1.5 mm. *Shell:* conic-elongate; slender; smooth; brown to white. *Spire:* protoconch of two small whorls; teleoconch of six convex whorls which become angulate abapically; suture deeply impressed. *Sculpture:* microscopic growth striae only. *Aperture:* subcircular, oblique. *Color:* glossy brown, red-brown or white.

D. scopulorum is less common than *D. varia*, occurring in sediments at depths greater than 40 m.

This species was described from the Hawaiian Islands.

Diala varia A. Adams, 1861. Fig. 44 A. (Synonym: *Barleeia imbricata* Watson, 1886.) Length, 2 mm; diameter, 1 mm. *Shell:* conic-ovate; smooth; brown with a spiral of brown and white spots. *Spire:* protoconch of one and one-half smooth, brown whorls; teleoconch of five flat-sided whorls; suture narrow, channeled. *Sculpture:* microscopic growth striae only on the apical whorls, base striated by 8 threads. *Aperture:* ovate; peristome incomplete; outer lip thin, smooth. *Color:* glossy brown with an articulated brown and white spiral band just below the suture and a paler band at the periphery of the last whorl; occasionally dark brown or cream.

These shells are occasionally found on reefs, but are common to abundant in sediments from depths of 10 to 50 m.

D. varia was described from "China and Japan" and appears to be rather widely distributed in the Pacific Ocean, from New Caledonia and Tahiti to southern Japan.

Finella pupoides A. Adams, 1860b. Fig. 44 G. Length, 3 mm; diameter, 1 mm. *Shell:* conic-ovate; with fine axial and spiral threads; cream to brown. *Spire:* protoconch of two or three smooth brown or cream whorls; teleoconch of four or five

conspicuously convex whorls a little angled at the suture; suture distinct, deep. *Sculpture:* fine spiral threads with subequal interspaces distributed over all the whorls and with axial threads which become obsolete on the later whorls. *Aperture:* subovate; outer lip thin; columella a smooth arch. *Color:* variable — brown on the apical whorls, remaining whorls brown or cream.

F. pupoides is common where there are anaerobic sediments on fringing reefs and to depths of 40 m.

This species was described from "China and Japan" and appears to be distributed throughout the Indo-West Pacific from Mauritius to Australia, Micronesia, and Polynesia. *Obtortio pyrrhacme* Melvill and Standen, 1896, from Lifu is a synonym.

Scaliola bella Adams, 1860a. Fig. 44 I. (Synonym: *Scaliola caledonica* Crosse, 1872, Watson, 1886.) Length, 4 mm; diameter, 2 mm. *Shell:* conical-ovate; thin; with strongly convex whorls agglutinated with sand grains; white. *Spire:* protoconch of three and one-half whorls, the apical smooth, the next with axial ribs, the last unicarinate; teleoconch of five convex whorls; suture deeply impressed. *Sculpture:* faint axial striae; sand grains agglutinated irregularly on the abapical whorls. *Aperture:* subcircular; outer lip thin; sometimes partially disjunct. *Color:* white.

These shells are common in sediments at depths of from 20 to 45 m.

S. bella was described from Japan. Adams's descriptions of *Scaliola* are insufficient for modern determination of species, but comparison of Hawaiian shells with presumed type material (in the British Museum (Natural History)) indicates reasonable similarity.

Scaliola glareosa A. Adams, 1862b. Fig. 44 J. Length, 3 mm; diameter, 1 mm. *Shell:* conical; with convex whorls agglutinated with sand; white. *Spire:* protoconch of three whorls, the apical smooth, the next with axial ribs, the third unicarinate; teleoconch of four convex whorls; suture deeply impressed. *Sculpture:* faint axial striae; whorls agglutinated with sand grains. *Aperture:* subcircular, almost directly in line with the axis; outer lip thin, sometimes slightly separated from the last whorl. *Color:* white.

S. glareosa is common to abundant in sediments at depths of from 10 to at least 60 m.

This species was described from Japan. *S. glareosa* is distinguished from *S. bella* by its narrower shell.

Scaliola gracilis A. Adams, 1862b. Fig. 44 K. Length, 3 mm; diameter, 2 mm. *Shell:* conical; with convex whorls sparsely agglutinated with sand grains; white. *Spire:* protoconch of three whorls, the apical smooth, the next with axial threads, the third unicarinate; teleoconch of five convex whorls; suture deeply impressed. *Sculpture:* faint axial striae; whorls sparsely covered with sand grains. *Aperture:* circular; outer lip thin; last whorl somewhat separated from the penultimate whorl. *Color:* white.

These shells are found in sediments at depths of from 3 to 60 m. They are less common than are the shells of *S. bella* and *S. glareosa*.

S. gracilis was described from Japan. The shells are distinguished from those of the other two species by the lesser numbers of sand grains and partially detached last whorl.

Styliferina goniochila (A. Adams, 1860b). Fig. 44 H. Length, 3 mm; diameter, 1.25 mm. *Shell:* conic with a styliform apex; transparent with a spiral of white blotches around the periphery of the last whorl. *Spire:* protoconch styliform, of six whorls, the apical two whorls white, the others with a subsutural streak of dark brown; teleoconch of four convex whorls; suture impressed. *Aperture:* subovate; outer lip thin; columella barely sinuous. *Sculpture:* growth striae only. *Color:* transparent, a spiral of opaque white blotches around the periphery of the last whorl, sometimes also at the suture of others; apical whorls tinted red-brown. *Animal:* Head, foot, anterior part of the mantle and tentacles brown or gray-white, mottled with flake white, tentacles slender and very long in proportion to the length of the body.

These gastropods are locally common at depths of from 2 to 30 m, especially on Hawaii. They are remarkable for their fast growth rates and short life span: from premetamorphic veligers to reproductive adult requires less than three weeks (J. B. Taylor, 1975). They are herbivorous, feeding on detritus and algal film.

S. goniochila was described from Japan and has also been recorded from Cape York, Australia (R. B. Watson, 1886).

Family **Cerithiidae**

Cerithids are distinguished by their elongate, high-spired shells with a short but distinct anterior canal. The sculpture consists of beaded spiral cords, axial ribs, and nodules. Cerithid shells are especially noteworthy for the range of variation in size, form, color, and sculpture which is found even in a single species. This variability has led to the introduction of a plethora of names: in the western Atlantic alone, Houbrick (1974) reduced 41 taxa to six valid species.

The sexes are separate, and the males aphallic. The eggs are deposited either as a tangled mass or flattened coils in gelatinous strings attached to the substratum. Larvae of most species are planktotrophic with unpigmented velar lobes (J. B. Taylor, 1975), but some species have direct development (Houbrick, 1973; Cannon, 1975).

In Hawaii, as elsewhere in the tropics, cerithids are among the most common and abundant of shallow water mollusks. *Bittium parcum* and *B. zebrum* are the dominant microgastropods of tide pools and reefs, and *Cerithium atromarginatum* and *C. egenum* are common in the algal-sand mat of tide pools. Subtidally *Rhinoclavis fasciata* may be locally common in sand at depths of 60 m. Cerithids are algal-detritus feeders.

The genera of Cerithiidae found in Hawaiian waters may be keyed as follows:

1. Shell elongate, high-spired 2
   Shell trochoid ..... *Plesiotrochus*
2. Anterior canal well-developed and slotlike 3
   Anterior canal spoutlike, not well developed ..... *Bittium*
3. Columella smooth, without folds ..... *Cerithium*
   Columella with folds ..... *Rhinoclavis*

Bittium impendens (Hedley, 1899). Fig. 45 A. Length, 4 mm; diameter, 2 mm. *Shell:* stout, conic, turreted; with spiral striae and strong axial buttresses; light brown. *Spire:* protoconch of two and one-half finely punctate whorls; teleoconch of six to

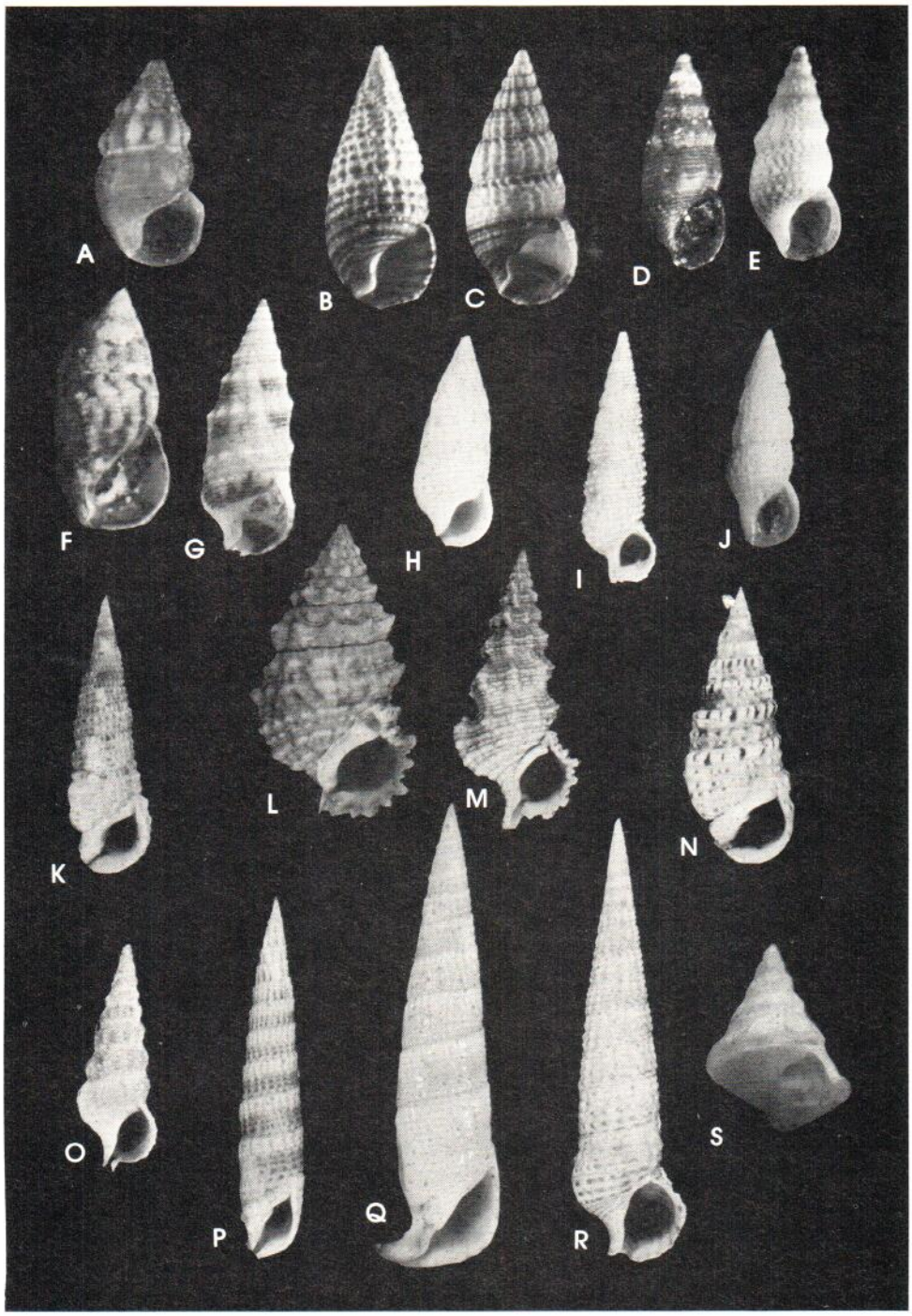


Figure 45.—**Cerithiidae.** A. *Bittium impendens*, length 4 mm. B, C. *B. zebrum*, two color forms, length 5 mm. D, E. *B. parcum*, two color forms, length 3.5 mm. F. *Cerithium atromarginatum*, length 14 mm. G. *C. egenum*, length 8 mm. H. *C. nesioticum*, length 15 mm. I. *C. interstriatum*, length 12 mm. J. *C. placidum*, length 6 mm. K. *Rhinoclavis articulata*, length 46 mm. L. *Cerithium mutatum*, length 34 mm. M. *C. columna*, length 43 mm. N. *Rhinoclavis sinensis*, length 50 mm. O. *Cerithium rostratum*, length 21 mm. P, Q. *Rhinoclavis fasciata*, two color forms, length 23 and 30 mm. R. *Cerithium matukense*, length 69 mm. S. *Plesiotrochus luteus*, length 4 mm.

eight convex whorls; suture moderately impressed. *Sculpture:* apical whorls with two or three fine, granular threads; abapical whorls with strong axial buttresses which are weaker at the suture than on the periphery of the whorl, the buttresses overridden by close-set spiral threads; a prominent varix on the last whorl opposite the aperture. *Aperture:* subcircular; columella sharply sinuate; anterior canal short and broad. *Color:* apical whorls purple-red, abapical whorls light brown, the buttresses sometimes almost white.

These cerithids are common at depths of more than 6 meters from Kauai to Oahu and abundant at depths of less than one meter to more than 20 meters off the leeward coasts of Maui and Hawaii where they comprise the dominant component of micromolluscan assemblages associated with subtidal coral communities.

B. impendens was described from Funafuti and has been reported from Holocene drill holes at Enewetak, Marshall Islands (Ladd, 1972).

Bittium parcum (Gould, 1861). Figs. 22 D; 45 D, E. (Synonym: *Bittium hawaiienses* Pilsbry and Vanatta, 1905.) Length, 3.5 mm; diameter, 1.5 mm. *Shell:* conic, turreted; spirally striate; dark brown to cream. *Spire:* protoconch of one and one-half shining buff whorls; teleoconch of five somewhat convex whorls; suture impressed. *Sculpture:* apical whorls distinctly keeled at the sutures with fine spiral striae between the keels; abapical whorls with somewhat sinuous and variously developed butresslike axial ribs crossed by fine spiral striae; a single varix on each whorl. *Aperture:* ovate; outer lip evenly arcuate; siphonal notch sharp, deep, and flaring. *Color:* variable — cream with opaque spirals; cream with dark brown spirals; or dark brown.

These cerithids are among the most abundant of all mollusks in tide pools and on solution benches and reefs, occurring by the thousands on algae such as *Valonia, Boodlea, Microdictyon,* and *Padina.* Development is direct, the juveniles emerging from gelatinous egg masses deposited on algae and rubble.

B. parcum was described from the Ryukyu Islands.

Bittium zebrum (Kiener, 1841). Fig. 45 B, C. (Synonyms: *Cerithium pusillum* Gould, 1849; *C. boeticum* Pease, 1861b; *C. paxillum* Pease, 1861b; *C. unilineatum* Pease, 1861b.) Length, 5 mm; diameter, 3 mm. *Shell:* conic-elongate; with beaded spiral threads; brown, cream, or white with brown banding. *Spire:* protoconch of three white or brown whorls, the apical smooth, the next two carinate; teleoconch of five or six slightly convex whorls; suture slightly constricted. *Sculpture:* five spiral threads obsoletely to distinctly beaded; base with spiral threads; occasional varices on the whorls. *Aperture:* ovate; columella stout, glazed by a thin callus; siphonal canal prominent and projecting beyond the lip; outer lip thick, sometimes lirate within. *Color:* variable — white peppered with brown, white with a narrow brown spiral at the suture (*B. unilineatum* (Pease)), light brown with darker brown banding (*B. boeticum* (Pease)), dark brown (*B. paxillum* (Pease)). *Animal:* exposed parts creamy yellow flecked with white and smudged with sooty freckles.

These cerithids are abundant on fringing reefs, less common in tide pools, and rarely found on benches or in sediments to depths of 15 m. They are rubble-associated, usually found under rocks. Pleistocene fossils are reported from Molokai (Ostergaard, 1939, as *Cerithium boeticum*).

B. zebrum is widespread in the Indo-West Pacific where it exhibits a variety of color forms (Vignal, 1903).

Cerithium atromarginatum Dautzenberg and Bouge, 1933. Fig. 45 F. (Synonyms: *Cerithium maculosum* Mighels, 1845, non Kiener, 1841; *C. nassoide* Sowerby, 1855.) Length, 14 mm; diameter, 5 mm. *Shell:* conic-obese; solid; with obscurely beaded spiral threads; fawn mottled with light and dark brown. *Spire:* protoconch of three and one-half red-brown whorls, the apical smooth, the others with fine axial ribbing and spiral keels; teleoconch of four or five slightly inflated whorls; suture shallow. *Sculpture:* obscurely beaded spiral threads equal in diameter to the interspaces; with occasional axial varices. *Aperture:* ovate; outer lip thick; siphonal canal short, barely recurved. *Color:* fawn mottled with white, light brown and with occasional splashes of dark brown. *Animal:* tentacles, mantle and foot creamy white mottled with light and dark brown; proboscis and siphon also flecked with yellow.

These cerithids are common buried in sand and under rocks and rubble in tide pools and in the algal-sand mat on solution benches. Shells are occasionally found in sediments to depths of 13 m. The veligers are bilobed; metamorphosis occurs when three to three and one-half whorls are complete at a length of 325 μm (J. B. Taylor, 1975).

C. atromarginatum occurs throughout the Indo-West Pacific, from Mauritius and the Cocos-Keeling Islands (Maes, 1967) to the Ellice Islands (Hedley, 1899), the Society Islands (Dautzenberg and Bouge, 1933) and the Marshall Islands.

Cerithium columna Sowerby, 1834. Fig. 45 M. Length, 43 mm; diameter, 28 mm. *Shell:* conic-elongate; solid; spirally corded and axially noduled; fawn. *Spire:* protoconch of three and one-quarter red-brown whorls with axial threads and spiral striae; eight to ten whorls; suture shallow; indistinct. *Sculpture:* distinct spiral cords of greater diameter than the interspaces crossing sharply noduled axial ribs. *Aperture:* ovate; outer lip flaring and fluted by the external sculpture; siphonal canal short, briefly recurved. *Color:* fawn; often encrusted with coralline algae.

C. columna is fairly common, occurring both in the intertidal in tide pools and subtidally to depths of 100 m. Pleistocene fossils are reported from Molokai (Ostergaard, 1939).

This species is well known throughout the Indo-West Pacific.

Cerithium egenum Gould, 1849. Fig. 45 G. Length, 8 mm; diameter, 3 mm. *Shell:* conic-slender; with obscurely beaded spiral threads; cream splashed with dark brown at the base of the last whorl. *Spire:* protoconch of three and one-half ovate whorls, the apical one and one-half whorls smooth and white, the abapical whorls brown, axially ribbed from the suture and with two keels; teleoconch of eight barely convex whorls; suture indistinct. *Sculpture:* each whorl with a large, granular spiral about the center, remainder of whorl with spiral threads; with occasional axial varices. *Aperture:* ovate; outer lip thick; siphonal canal short, not recurved. *Color:* cream with a splash of dark brown on each whorl, the last whorl with a dark band below the periphery and extending over the outer lip.

These cerithids are occasionally found buried in sand in tide pools and on benches, sometimes with *C. atromarginatum*. The veligers are bilobed; they

metamorphose when three to three and one-quarter whorls are complete, at a length of 500 μm (J. B. Taylor, 1975).

C. egenum ranges throughout the Indo-West Pacific from the Red Sea and Cocos-Keeling Islands (Maes, 1967) to the Marshall and Society Islands.

C. egenum is distinguished from *C. atromarginatum* by its slender shape, distinctive color pattern, and larger protoconch.

Cerithium interstriatum Sowerby, 1855. Fig. 45 I. (Synonyms: *Cerithium fucatum* Pease, 1861b; *C. clavis* Sowerby, 1865; *Cerithium thaanumi* Pilsbry and Vanatta, 1905.) Length, 12 mm; diameter, 4 mm. *Shell:* conic-elongate, inflated; with beaded spiral threads; cream occasionally splashed with dark brown. *Spire:* protoconch of three brown whorls, the apical smooth and mamillate, the others with two spiral keels, the apical keel smooth, the abapical beaded; teleoconch of five to ten convex whorls; suture shallow, oblique on the apical whorls. *Sculpture:* somewhat variable — apical whorls clathrate, later whorls usually with about three spirals of elongate beads on each whorl, the interspaces twice the diameter of the spirals and often with smooth threads between; suture bordered by a thread. *Aperture:* subovate; outer lip thin; base concave, encircled by a beaded spiral; siphonal canal short. *Color:* fawn splashed with brown.

These cerithids are common on fringing reefs.

C. interstriatum has also been recorded from the Red Sea (Jousseaume, 1931).

Cerithium matukense Watson, 1886. Fig. 45 R. Length, 69 mm; diameter, 15 mm. *Shell:* conic-elongate; with beaded spiral threads; cream spirally banded with brown. *Spire:* teleoconch of about 18 barely convex whorls; suture impressed, shallow. *Sculpture:* four spiral threads on each whorl, the apical spirals more prominently beaded than the last whorl; base of the last whorl with five smooth threads; interspaces between the spirals smooth and of greater diameter than the threads; whorls with occasional varices. *Aperture:* subcircular; outer lip thin and flaring; columella straight; siphonal canal recurved.

Shells are rarely found, occurring at depths of 40 m.

C. matukense was described from Fiji from shells dredged at depths of 310 fathoms.

Cerithium mutatum Sowerby, 1834. Fig. 45 L. (Synonym: *Cerithium echinatum* Lamarck, Tinker, 1952.) Length, 34 mm; diameter, 15 mm. *Shell:* conic-obese; solid; with a row of spiny nodules on each whorl; fawn. *Spire:* protoconch of two small whorls, the apical whorl smooth, the abapical with two spiral keels; teleoconch of eight to ten whorls, the apical whorls tapering, the last whorl ventricose; suture barely impressed. *Sculpture:* a single series of spiny nodules on each whorl except the last which has two, and with obsoletely granuled, weak spiral cords unevenly distributed over the whorls. *Aperture:* ovate; outer lip fluted by the external sculpture; siphonal canal short, barely recurved. *Color:* fawn with occasional brown flecks.

C. mutatum is a common species occurring from the intertidal to depths of 100 m. These gastropods are usually found lying on sand or rubble under algal-covered rocks.

This species is widely distributed throughout the Indo-West Pacific.

Cerithium nesioticum Pilsbry and Vanatta, 1905. Fig. 45 H. (Synonyms: *Cerithium pusillum* Nuttall, Jay Cat., 1839; *nomen nudum; C. lacteum* Kiener, Martens and Langkavel, 1871; *C. voyi* Pilsbry and Vanatta, 1905.) Length, 15 mm; diameter, 7 mm. *Shell:* conic-obese; inflated; with finely beaded spiral threads; white. *Spire:* protoconch of three smooth, white whorls; teleoconch of six inflated whorls; suture barely impressed. *Sculpture:* fine, alternating larger and smaller beaded spiral threads, the larger threads often obsoletely granular. *Aperture:* subovate; outer lip simple; siphonal canal barely recurved. *Color:* white with occasional faint brown splashes.

This is one of the most commonly occurring of the shallow-water Hawaiian cerithids, found in sand in tide pools and on fringing reefs.

C. nesioticum occurs throughout the Pacific Ocean and in the Indian Ocean (Tomlin, 1935a). The Hawaiian shells are distinguished from those occurring elsewhere by their more prominent granules and the brown splashes on the white background.

Cerithium placidum Gould, 1861. Fig. 45 J. Length, 5 mm; diameter, 1.5 mm. *Shell:* elongate-conic, slender; with obsoletely beaded spiral threads; usually white. *Spire:* protoconch of four brown whorls, the two apical whorls smooth, the remaining two with spiral keels; teleoconch of about 10 slightly convex whorls; suture shallow. *Sculpture:* two or three apical whorls below the protoconch with a barely beaded spiral and a smooth spiral thread, abapical whorls with about seven delicately beaded spiral threads, the interspaces twice the diameter of the threads and faintly striated. *Aperture:* sub-ovate, outer lip thin; base concave, encircled apically by a beaded spiral; anterior canal short, barely recurved. *Color:* variable — usually white but sometimes light brown or lavender.

Shells are common in beach drift and occasionally found in sediments to depths of 26 m.

C. placidum was described from Okinawa. Shells are distinguished from those of *C. interstriatum* by their smaller size, usually finer sculpture, and by the predominantly spiral sculpture of the apical whorls (the apical whorls in *C. interstriatum* are clathrate).

Cerithium rostratum Sowerby, 1855. Fig. 45 O. (Synonym: *Cerithium gracile* Pease, 1861b.) Length, 21 mm; diameter, 17 mm. *Shell:* conic-elongate; slender; turreted; with fine spiral beading and a prominent varix on the last whorl; cream, siphonal canal tipped with dark brown. *Spire:* teleoconch of about 11 convex whorls; suture impressed. *Sculpture:* apical whorls with buttressed axial ribs noduled by spiral cords; spiral threads alternating in size with two or three smaller threads sandwiched between larger cords; last whorl with a prominent varix extending from the suture to the siphonal canal and with occasional smaller varices on the other whorls. *Aperture:* ovate; outer lip thin and flaring; columella straight; siphonal canal barely recurved. *Color:* fawn with occasional dark brown spots on the spirals; siphonal canal tipped with dark brown.

This is a rarely found shell in Hawaiian waters, occurring at depths of about 3 m.

C. rostratum is distributed throughout the Indo-West Pacific.

Rhinoclavis articulata (Adams and Reeve, 1850). Fig. 45 K. (Synonym: *Vertagus graniferus* Pease, 1861b.) Length, 46 mm; diameter, 12 mm. *Shell:* conic-elongate, slender; solid; with sharply granular spirals and a prominent varix on the last whorl; cream spotted with dark brown. *Spire:* teleoconch of twelve whorls; suture indistinct. *Sculpture:* beaded spiral threads separated by interspaces of equal diameter, the subsutural spiral wider than the others and with sharp plaits. *Aperture:* ovate; outer lip thin, barely fluted; columella with a single plait and a heavy enamel shield; siphonal canal elongate, recurved. *Color:* fawn with splashes of lighter and darker brown.

These cerithids are common in sand at depths of from 1 to 160 m.

This species occurs throughout the Indo-West Pacific.

Rhinoclavis fasciata (Bruguière, 1792). Fig. 45 P, Q. (Synonyms: *Cerithium hawaiiensis* (Dall ms.) Tinker, 1952; *C. pharos* (Hinds), Tinker, 1952.) Length 25 mm; diameter, 7 mm. *Shell:* elongate-conic, slender; relatively smooth axial plications forming low ribs and incised spiral lines; color variable — white or cream, sometimes with brown. *Spire:* protoconch of about three whorls; teleoconch of 12 to 14 whorls, rather straight-sided; suture distinct, undulated or crenulated by the ends of the axial ribs. *Sculpture:* axial plications forming small, straight, low, rounded ribs (about 20 on the penultimate whorl), sometimes extending from suture to suture, at other times extending only about half the length of the whorl; ribs crossed by incised spiral lines forming flat cords, the cords sometimes granular. *Aperture:* narrowly ovate, with a single plait on the columella and a thick, blunt denticle on the base of the columella callous; siphonal canal strongly recurved. *Color:* variable — white or cream, sometimes with brown in spiral bands and occasional brown spots.

These cerithids are sand-dwellers, found at depths of 30 to 200 m.

R. fasciata is widely distributed throughout the Indo-West Pacific. Small shells (about 20 to 24 mm in length) with brown spiral bands were given the name "hawaiiensis" by Dall, and that name was used by Tinker (1952) but has no taxonomic validity. Houbrick (1978) considers these Hawaiian shells as ecophenotypic variations, noting similar shells are found in the Caroline Islands and Zanzibar.

Rhinoclavis sinensis (Gmelin, 1791). Fig. 45 N. (Synonym: *Clava obeliscus* Bruguière, Edmondson, 1933.) Length, 50 mm; diameter, 20 mm. *Shell:* conic-elongate; inflated; solid; with a prominent varix and tubercled subsutural band; fawn spotted with brown and white. *Spire:* teleoconch of nine inflated whorls; suture indistinct. *Sculpture:* a tubercled, subsutural band on each whorl and spirals of beaded threads; axial ribs unevenly distributed. *Aperture:* ovate; outer lip thin and smooth; columella with two plaits; siphonal canal elongate and recurved. *Color:* fawn splashed with brown.

R. sinensis is a sand-dweller, found intertidally and to depths of 15 m. Fossils have been reported from Pleistocene deposits on Oahu (Ostergaard, 1928, as *Cerithium obeliscus*) and Molokai (Ostergaard, 1939).

This species ranges throughout the Indo-West Pacific.

Plesiotrochus luteus (Gould, 1861). Fig. 45 S. (Synonym: *Plesiotrochus exilis* Pease, Kosuge, 1969.) Length, 4 mm; diameter, 2 mm. *Shell:* trochoid; with a prominent spiral rib at the base of each whorl; yellow-white. *Spire:* acute, tapering;

whorls flattened and slightly convex in profile; suture indistinct. *Sculpture:* a prominent, sometimes obsoletely scalloped spiral cord at the base of each whorl; remainder of whorls finely spirally striate; periphery of last whorl with a sharp keel. *Aperture:* oblique, subquadrate; outer lip sculptured by the external spiral cord; anterior canal short. *Color:* cream with spiral threads or spots of purple brown, sometimes with an articulated purple line at the suture and periphery and another on the base.

Shells are occasionally found in sediments at depths of 10 to 30 m off Kauai and Oahu and are common at Midway and at depths of 1 to 10 m along the leeward coast of Hawaii. They occur in Pleistocene fossil deposits on Oahu (Kosuge, 1969, as *P. exilis* Pease).

This species occurs throughout the Indo-West Pacific, from Christmas Island in the Indian Ocean (as *P. fischeri* Smith, 1909) to the Marshall Islands, Loyalty Islands, and Line Islands, and in Miocene sediments in the Marshall Islands (Ladd, 1972).

Additional Records

Cerithium asperum Pease, 1861b, is a synonym of *C. morus* Bruguière, a well known Indo-West Pacific cerithid, but it was apparently erroneously described from the Hawaiian Islands. *C. lentiginosum* Sowerby, 1865, a thin, brown and white, high-spired shell with low axial ribs and faintly granular spiral threads also appears to have been erroneously attributed to the Hawaiian Islands.

C. sandvichense 'Sowerby' Reeve, 1865, described from the Sandwich Islands is not known to occur in Hawaii, but has been recorded from Tahiti, the Gambier Islands, Pitcairn Island, and Ducie Atoll (Rehder and Randall, 1975).

Family **Cerithiopsidae**

The shells of cerithiopsids resemble those of the Triphoridae in their elongate-cylindrical to pupiform shapes and sculpture of beaded spiral cords. Juvenile shells like those of the triphorids have a planulate base. In cerithiopsid shells, however, coiling is dextral, with the aperture to the right of the columella as it is in most other mesogastropods; the outer lip is comparatively simple, without a posterior sinus; and the protoconch is smooth rather than elaborately sculptured. The radula is also distinct from that of triphorids, and the taenioglossan radula of cerithiopsids allies them with other cerithiaceans.

Cerithiopsids feed and deposit their eggs on sponges (Lebour, 1933; Fretter, 1951), but the juveniles of at least one species *(Cerithiopsis arga)* feed on algal film in the laboratory (J. B. Taylor, 1975). The larvae hatch as bilobed veligers (J. B. Taylor, 1975).

Cerithiopsid shells are neither so common nor abundant as are those of triphorids which may outnumber cerithiopsids by more than twenty to one in sediments from depths of 10 to 60 m in Hawaiian waters. Nor are cerithiopsids often found alive, and the protoconch, which is a critical feature for specific determination, is often broken or missing entirely. Seven species are recorded here; at least four other species occur but material for proper determination is not presently available.

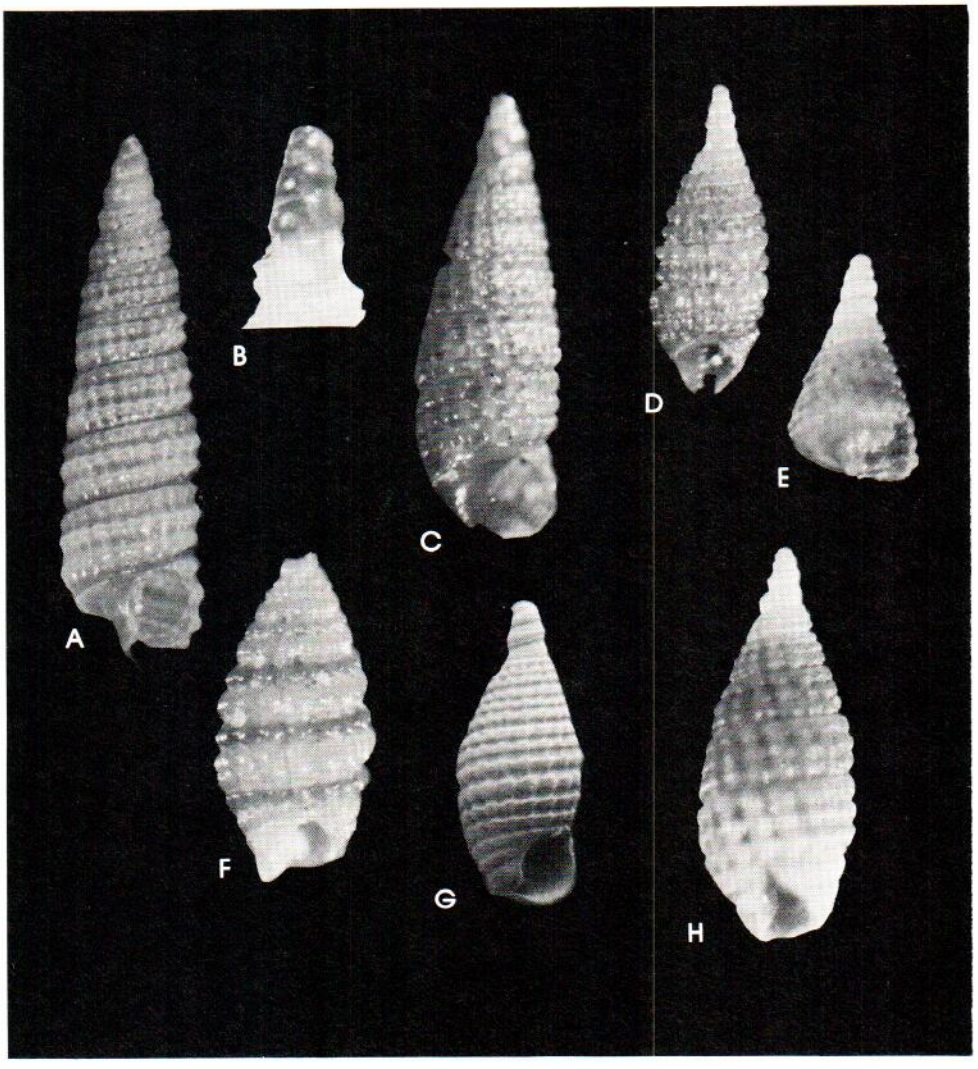


Figure 46.—**Cerithiopsidae.** A. *Cerithiopsis arga,* length 5.5 mm (holotype). B. *C. arga,* protoconch. C. *Joculator granata,* length 2.5 mm (holotype). D. *J. turrigera,* length 4 mm. E. *J. turrigera* juvenile, length 2 mm. F. *J. semipicta,* length 2.0 mm. G. *J. ridicula,* length 2 mm. H. *J. uveanum,* length 2.75 mm.

Cerithiopsis arga Kay, new species. Fig. 46 A, B. Length, 5.5 mm; diameter, 1.25 mm. *Shell:* slender, subcylindrical; with three rows of beaded spiral cords on each whorl; glistening cream with a brown line at the suture, occasionally all brown or all white. *Spire:* protoconch of four and one-half slender, conical, smooth whorls; teleoconch of eight to twelve rather flat-sided whorls; suture shallow, channeled. *Sculpture:* spiral sculpture of three subequal, close-set, beaded cords with narrower interspaces and a smooth cord at the margin of the base of the last whorl; axial sculpture of ribs recessed below the spirals; suture with a fine spiral thread. *Aperture:* subquadrate; outer lip thin; columella straight; siphonal canal barely produced. *Color:*

variable — glistening cream with a brown spiral at the suture and with the base of the last whorl brown, sometimes all cream or all brown.

This is the most common of the Hawaiian cerithiopsids, found in beach drift, in sediment on reef flats, and to depths of 60 m. The shells are variable in both size and color. The holotype, 5.5 mm in length, with 10 whorls, cream colored with brown suture and base represents the most often encountered color form. The veliger larvae are bilobed, the apical lobe twice the size of the abapical lobe; they metamorphose when four to four and three-quarters whorls are complete, at a length of 600 to 700 μm (J. B. Taylor, 1975).

Type locality: Kepuhi Point, Oahu, from a depth of 6.5 m. *Holotype:* Bernice P. Bishop Museum No. 9745. *Paratypes:* Australian Museum, British Museum (Natural History), United States National Museum.

The Hawaiian shells are distinguished from those of *C. rubricincta* Melvill, 1896, from Bombay by their broader outline and three rows of granules (there are two in *C. rubricincta*); from those of *C. filofusca* (Laseron, 1951) from New South Wales and *C. orientalis* Preston, 1905, from Ceylon by the narrower protoconch base; and from those of *C. hedista* Melvill and Standen, 1896, from Lifu, in color pattern (the abapical spiral in shells of *C. hedista* is honey yellow). Derivation of name: Greek adjective meaning shining or glistening. Refers to the glossy surface.

Joculator granata Kay, new species. Fig. 46 C. Length, 2.50 mm; diameter, 0.75 mm. *Shell:* ovate, cylindrical; with three rows of beaded spiral threads on each whorl; glistening yellow brown. *Spire:* protoconch of four and one-half wide, conical whorls, the penultimate usually eccentric and suture crimped; teleoconch of five rather straightsided whorls; suture impressed, barely noticeable. *Sculpture:* three beaded spiral threads on each whorl, base with an obsoletely beaded spiral; beads prominent, circular, separated by about one-half their own diameter; interspaces between spirals about equal in diameter to the beads and with recessed axial threads. *Aperture:* subcircular; columella nearly straight; siphonal canal short.

These cerithiopsids are uncommon, found in beach sand and in sediments to depths of 60 m.

Type locality: Kiholo, Hawaii, from sediments at a depth of 28 m. *Holotype:* Bernice P. Bishop Museum No. 9774. *Paratypes:* Australian Museum, British Museum (Natural History), U. S. National Museum.

The minute shells are distinguished from those of other cerithiopsids by their small size, neat pattern of beaded spiral threads, ovate-cylindrical shape, and the crimped suture in the protoconch. They are perhaps closest in shape to the shells of *Conciliopsis carrota* Laseron, 1955, from Queensland, Australia, but differ in their smaller size and distinctive protoconch. Derivation of name: *granata,* Latin adj. — having many grains or seeds. Suggested by the pattern of beading comprising the sculpture of the shells.

Joculator ridicula (Watson, 1886). Fig. 46 G. Length, 2 mm; diameter, .75 mm. *Shell:* ovate; with three beaded spirals on each whorl; brown. *Spire:* protoconch of four conical, convex whorls; teleoconch of four rather flat-sided whorls; suture deeply furrowed. *Sculpture:* three beaded spiral cords on each whorl, the apical row slightly larger than the others; beads closely spaced on the cords and joined by small axial columns; base with one obsoletely beaded spiral and another smooth cord. *Aperture:*

ovate; outer lip sculptured by the spiral cords. *Color:* glossy brown, protoconch white.

These shells are uncommon in sediments at depths of 3 m.

J. ridicula was described from Wednesday Island, northeastern Australia.

Joculator semipicta (Gould, 1861). Fig. 46 F. Length, 2.0 mm; diameter, 0.9 mm. *Shell:* ovate; two spirals of coarse beads on each whorl; yellow spirally banded with brown. *Spire:* protoconch slender, conical; of about four whorls; teleoconch of six convex whorls; suture in a deep furrow. *Sculpture:* two spiral rows of coarse beads on each whorl, the apical beads larger and elongated axially, a third row on the base. *Aperture:* small, lenticular. *Color:* protoconch white; yellow-white with a broad spiral band of brown on each whorl.

These cerithiopsids are uncommon, occasionally found in sediments at depths to 10 m.

J. semipicta was described from the "China Seas"; the species is also known from Fiji (as *Cerithiopsis balteata* Watson, 1880), and from Holocene and Miocene drill holes at Enewetak, Marshall Islands (Ladd, 1972).

Joculator turrigera (Watson, 1886). Fig. 46 D, E. Length, 3 mm; diameter, 0.8 mm. *Shell:* ovate; with two beaded spirals on each whorl; light yellow brown. *Spire:* protoconch of five slender, conical white whorls; teleoconch of five convex whorls; suture shallow. *Sculpture:* spiral sculpture of two close-set, prominent rows of beads with narrower interspaces, and on the last whorl a third nearly smooth cord at the margin of the base; axial sculpture not evident. *Aperture:* rounded; siphonal notch deep; canal not produced. *Color:* glistening light yellow-brown.

Shells of *J. turrigera* are the most common of all the cerithiopsids at depths of more than 20 m.

J. turrigera was described from the Hawaiian Islands.

Joculator uveanum (Melvill and Standen, 1896). Fig. 46 H. Length, 2.75 mm; diameter, 1 mm. *Shell:* ovate, inflated; with three rows of spiral granules; light brown. *Spire:* protoconch of four subulate, smooth whorls; teleoconch of five convex, inflated whorls; suture wide, oblique. *Sculpture:* three beaded spiral cords on each whorl, with a fourth spiral on the base of the last whorl, apical spiral largest, the others joined by nearly obsolete spiral threads. *Aperture:* subcircular; outer lip thin; columella short. *Color:* light brown, protoconch white.

These cerithiopsids are uncommon, found at depths of about 10 m.

J. uveanum was described from Lifu.

Superfamily TRIPHORACEA

Family **Triphoridae**

The Triphoridae is the only family among the marine gastropods in which most of the shells are sinistral, and the aperture is to the left of the shell axis. (Two subfamilies within the family accommodate dextrally coiled shells, however.) Triphorid shells are typically small (2.5 to 15 mm in Hawaii) but shells up to 40 mm

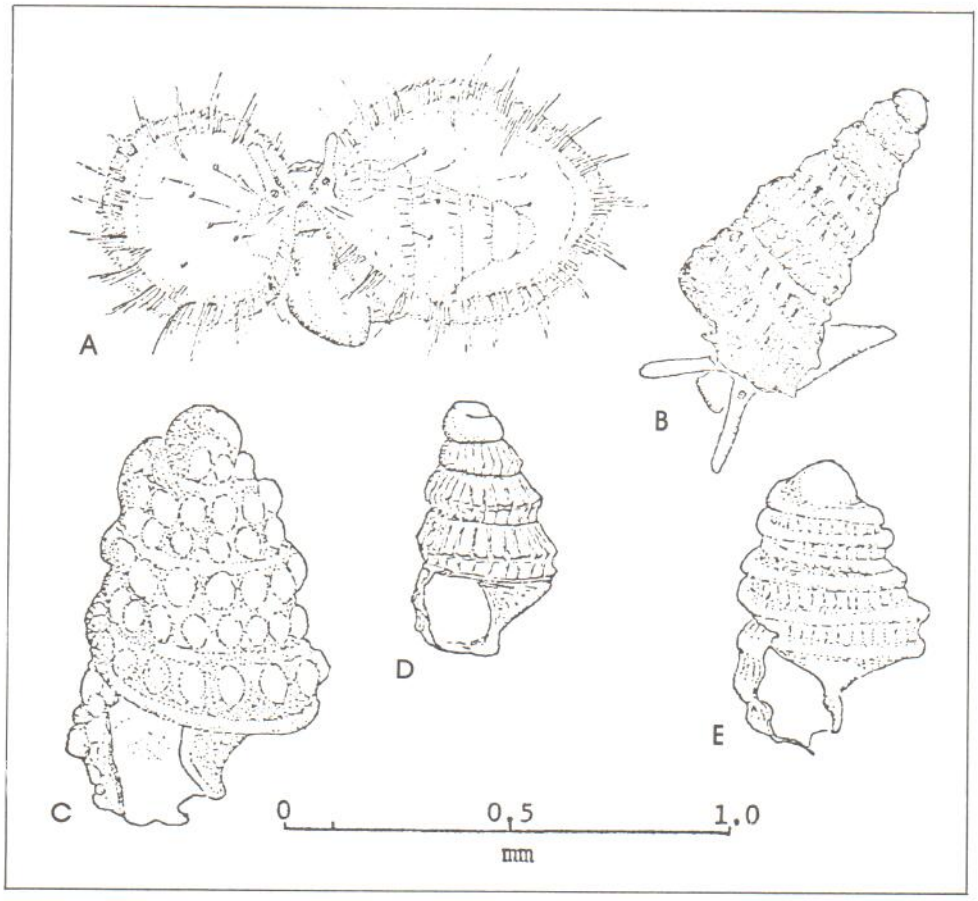


Figure 47.—**Triphoridae.** A. *Triphora peasi*, veliger larva showing bilobed velum with unequal lobes. B. *T. peasi*, juvenile shell. C. *Litharium maculata*, immersed, beaded protoconch. D. *Triphora* sp., with acuminate, carinate, and axially threaded protoconch. E. *Litharium* sp., short, immersed protoconch. (All after J. B. Taylor, 1975.)

in length have been described. They are conic-elongate, cylindrical or pupiform in shape and the sculpture is predominantly spiral, of smooth keels or beaded cords. Many triphorid shells are conspicuously colored, patterned in yellow and brown or lavender. One of the most distinctive features of these shells is the aperture. Whereas in the superficially similar cerithiopsid shells the aperture is comparatively simple, in triphorid shells there are well-developed anterior and posterior canals. The anterior canal, a shallow groove and relatively short in most other mesogastropods, is often distinctly tubular in triphorids, formed by a spur of the outer lip. The posterior canal, a slit or notch in some triphorids, may also develop as a circular orifice or a long tube (in the genus *Iniforis*), the so-called "third aperture."

Triphorids are associated with sponges, crawling on the surface and buried within, and most apparently feed on sponges (Kosuge, 1966). The radula is quite different from the taenioglossan radula of cerithiaceans, with distinctly cusped rachidian teeth and numerous laterals (Kosuge, 1966). The veliger larvae are bilobed with unequal

velar lobes, the left larger than the right (Fig. 47 A) (J. B. Taylor, 1975). Four types of protoconchs can be distinguished among the Hawaiian triphorids: an acuminate, conical form with spiral carinae or keels overrun by axial threads (Fig. 47 B, D), a dome-shaped paucispiral type with axial ribs (Fig. 47 E); an immersed form in which the protoconch consists of a single small whorl projecting from the beaded apical whorl of the teleoconch (Fig. 47 C); and an acuminate, conical or blunt-tipped type with microscopic wavy spiral threads (Fig. 48 K).

Triphorids occur from the intertidal to depths of more than 100 m, and are often found in fairly large numbers. In Hawaii they are abundant in beach drift and form up to 15 per cent of the microgastropods in sediments from coral communities at depths of 10 to 30 m.

As with many small mollusks, the taxonomy of the Triphoridae is in an unsatisfactory state. More than 20 genera and subgenera have been proposed, based on sculpture, the shape and position of the anterior and posterior canals, protoconch form and sculpture, and radular and opercular characters (Hinds, 1843; Jousseaume, 1884; Dall, 1924; Laseron, 1954, 1958b; Kosuge, 1966). Several features of the shell contribute to difficulties both in arriving at a satisfactory classificatory scheme and in the identification of species. The development of the anterior and posterior canals varies with the age of the animal; the number of whorls of the protoconch may be dependent on length of larval life; juvenile shells in some species are pyramidal with a planulate base and quite different in shape from the adult shells; and teleoconchs which are apparently similar in sculpture and color pattern may have quite dissimilar protoconchs (see for example *Cautor intermissa* and *Mastonia troglodytes*).

In the following account, I follow Kosuge's (1966) arrangement of subfamilies based on differences in operculum and radula, and include Marshall's (1977) subfamily Metaxiinae which accommodates some dextral triphorids.

Subfamily **Metaxiinae**

The distinguishing features of the shells in this subfamily, recognized by Marshall (1977), are a simple aperture lacking the well-developed anterior and posterior canals of other triphorids, and a protoconch with peculiar microscopic zigzag threads on the adapical whorls (Fig. 48 K). The shells are dextrally coiled, tall and slender, with a narrowly conical outline. The sculpture consists of spiral and axial threads or ribs which are nodular at the intersections. A periostracum is present in some species (Marshall, 1977). Three genera are presently recognized, with the genus *Metaxia* apparently worldwide in distribution (Marshall, 1977).

Metaxia albicephala Kay, new species. Fig. 48 L, M. Length, 4 mm; diameter, 0.90 mm. *Shell:* conical, narrow; dextrally coiled and with a cerithiopsidlike aperture; four beaded spiral threads on each whorl; white. *Spire:* protoconch of two and one-half white whorls, the apical whorl partly immersed and microscopically spirally striate; penultimate whorl with angular axial ribs and the abapical whorl smooth; teleoconch of six or seven slightly convex whorls; suture impressed, wide, shallow. *Sculpture:* spiral sculpture of four lightly beaded threads on each whorl, the beads rather flattened, more prominent on the last three threads, somewhat obsolete on the apical thread; suture with a spiral thread; base with a single cord. *Aperture:* subquadrate; base excavate; columella vertical; outer lip thin; anterior canal widely notched. *Color:* white.

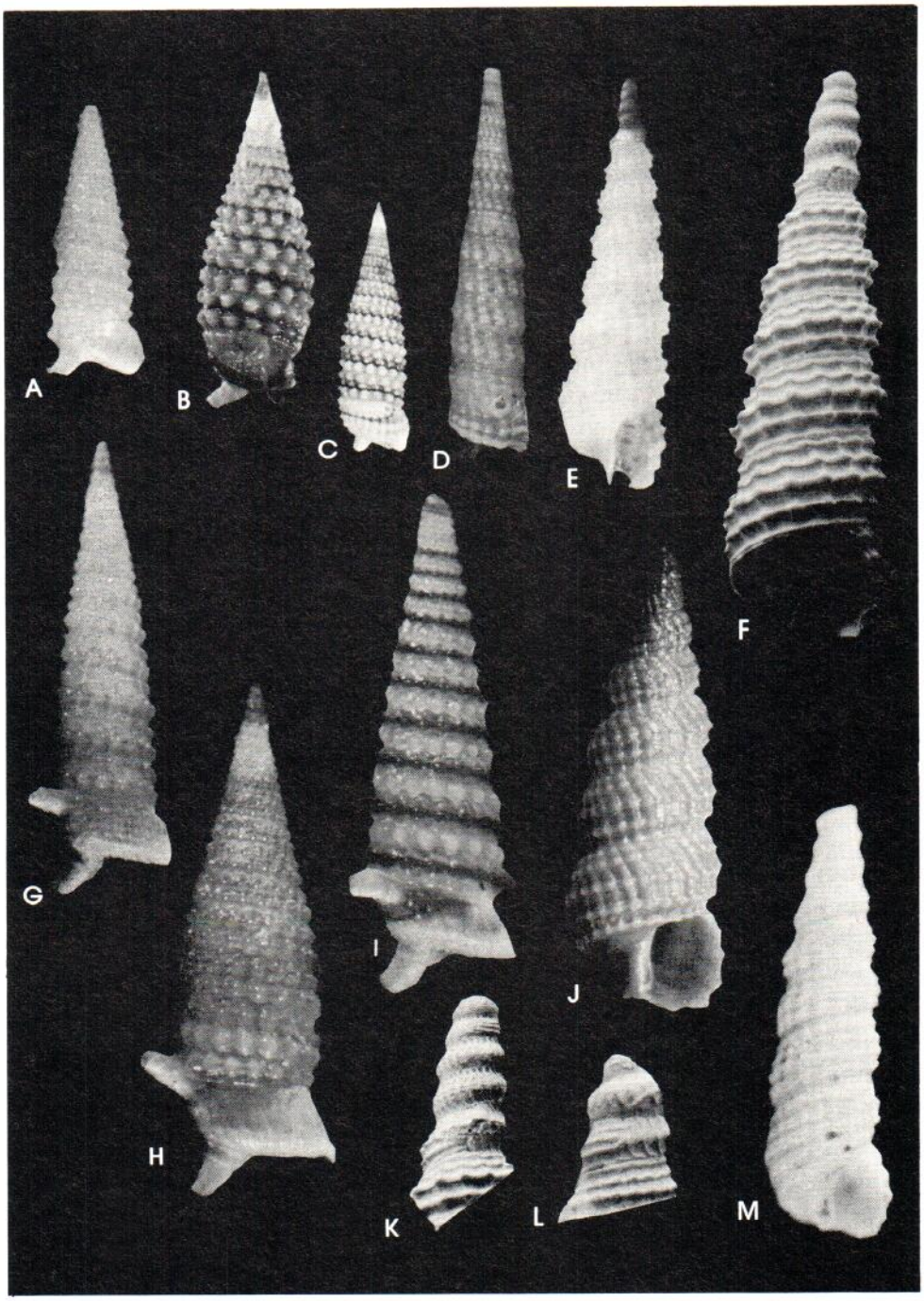


Figure 48.—A. *Iniforis peleae*, length 2.5 mm. B. *I. aemulans*, shallow form, length 13 mm. C. *I. aemulans*, deep form, length 10 mm. D. *I. concors*, length 15 mm. E, F. *Metaxia brunnicephala*, length 3 mm (holotype). G. *Iniforis ordinata*, length 5.5 mm. H. *I. hinuhinu*, length 7 mm (holotype). I. *I. perfecta*, length 7 mm. J. *Metaxia tricarinata*, length 8 mm. K. *Metaxia brunnicephala* protoconch. L, M. *M. albicephala*, Holotype length 5 mm (holotype) (M), protoconch (L).

These shells are common in beach drift and sediments to depths of 12 m.

Type locality: Poipu Beach, Kauai, in beach drift. *Holotype:* Bernice P. Bishop Museum No. 9784. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells of *M. albicephala* are distinguished from those of *M. brunnicephala* from Hawaii and *M. exaltata* (Powell, 1930) from New Zealand by the distinctive white protoconch. The protoconch is also distinct from that of *M. kermadecensis* Marshall, 1977, from New Zealand, in lacking the prominent wavy spiral cords present in that species. Derivation of name: *album*, Latin — white; *kephalē*, Greek — head. Refers to the white protoconch.

Metaxia brunnicephala Kay, new species. Fig. 48 E, F, K. Length, 3 mm; diameter, 0.75 mm. *Shell:* conical; narrow, dextrally coiled and with a cerithiopsidlike aperture; four beaded spirals on each whorl; white, protoconch dark brown. *Spire:* protoconch of four dark brown, conical whorls, the apical with microscopic rippled threads (Fig. 48 F), the other whorls with a single spiral carina and axial threads; teleoconch of seven convex whorls; suture deeply impressed. *Sculpture:* spiral sculpture of four beaded threads, apical threads least prominent and becoming obsolete on the later whorls; a fifth cord on the base of the last whorl; interspaces between the spirals reticulated by numerous fine axial threads; axial sculpture of strong threads which override the spirals, breaking them into distinct tubercles. *Aperture:* subquadrate; base excavate; outer lip thin; anterior canal widely notched. *Color:* white, protoconch dark brown.

These right-handed triphorids are occasionally found in beach drift and in sediments to depths of 30 m. Shells are variable in length and occasionally may be streaked with red-brown.

Type locality: Poipu Beach, Kauai, in beach drift. *Holotype:* Bernice P. Bishop Museum No. 9782. *Paratypes:* U. S. National Museum.

These shells are distinguished by their tall, sculptured protoconch from those of *M. albicephala* from Hawaii and *M. kermadecensis* Marshall, 1977, from New Zealand. Although similar in sculpture and features of the protoconch to the shells of *M. exaltata* (Powell, 1930), from New Zealand, the teleoconch in that species is light, translucent brownish-yellow, mottled with red-brown axial streaks (Marshall, 1977). Derivation of name: *brūn*, Anglo-Saxon — brown; *kephalē*, Greek — head. Refers to the brown protoconch.

Metaxia tricarinata (Pease, 1861b). Fig. 48 J. Length, 8 mm; diameter, 2.5 mm (type dimensions). *Shell:* comparatively large, conical; with three spiral rows of sharply pointed nodules on each whorl; glistening chestnut brown. *Spire:* protoconch of one whorl, not sharply demarcated from the spire and with two spiral keels; teleoconch of seven or eight convex whorls; suture shallow, impressed. *Sculpture:* spiral sculpture of three sharply beaded cords on each whorl, four on the last whorl, sometimes with a faint spiral at the suture; peripheral cords most conspicuous, adapical cords almost obsolete; axial sculpture of arcuate riblets with wider interspaces intersecting the spiral cords and forming rectangular depressions between them; base smooth and concave. *Aperture:* subquadrate; simple; columella straight; siphonal canal barely produced. *Color:* glistening chestnut brown.

These shells are uncommon, found in beach drift.

M. tricarinata was described from the Hawaiian Islands. The shells are distinguished from those of other cerithiopsids by their large size, conspicuous beading, and short protoconch.

Subfamily **Iniforinae**

Three genera of sinistral triphorids are included in this subfamily by Kosuge (1966), two *(Iniforis* and *Epiforis)* with closed, tubular anterior and posterior canals, the so-called "three aperture condition," and the third, *Risbecia,* the shells of which lack the tubular posterior canal but the animals of which have a radula similar to that of *Iniforis. Iniforis,* with elaborate posterior and anterior canals and an acuminate protoconch is represented by six species in Hawaiian waters.

Iniforis aemulans (Hinds, 1843). Fig. 48 B-C. (Synonym: *Triphoris clavata* Pease, 1861b.) Length, 10 mm; diameter, 3 mm. *Shell:* conic-elongate, inflated; posterior canal a circular orifice; last whorl with two prominent beaded spiral threads; gray, suture banded with purple-brown. *Spire:* protoconch conic, acuminate, of five and one-half dark brown whorls, the apical one and one-half smooth, the next two unicarinate, remaining whorls strongly bicarinate overidden with axial threads; teleoconch of ten to thirteen inflated whorls; suture distinct, shallow. *Sculpture:* two strongly beaded spirals consisting of hemispherical bosses separated by spaces equal to about half their diameter, with a middle threadlike row of beads sometimes developed on the abapical whorls; interspaces and suture with fine spiral striae; base with two obsoletely beaded spiral threads. *Aperture:* subquadrate; posterior canal closed, forming a circular orifice at the edge of the outer lip; anterior canal tubular, recurved. *Color:* gray, spirally banded with dark purple-brown between the beaded spirals; apical whorls white.

These triphorids are found in shallow water under bare coral or limestone blocks and are common to depths of 100 m.

I. aemulans was described from the Pacific Ocean. Shells have been recorded from the Philippines, Fiji, Samoa, and the Line Islands, and from Holocene sediments at Bikini, Marshall Islands (Ladd, 1972, as *Triphora clavata* Pease). The Hawaiian shells vary in shape and size; larger, more inflated shells tend to be in shallow water, slender, smaller shells are at depths of more than 10 m. No differences in protoconchs of the two forms have been detected to warrant distinguishing two species.

Iniforis concors (Hinds, 1843). Fig. 48 D. (Synonym: *Triphoris fucata* Pease, 1861b.) Length, 15 mm; diameter, 3 mm. *Shell:* conic-elongate, straight-sided; posterior canal a circular orifice; last whorl with three beaded spirals; white stained with brown. *Spire:* protoconch acuminate, of four brown whorls, the apical mamillate, the others carinated with one or two keels and with axial threads; teleoconch of about 20 pyramidal whorls; suture shallow, distinct. *Sculpture:* apical whorls distinctly beaded with two spirals of circular beads and an intercalary thread, abapical whorls with two somewhat obsoletely beaded apical spirals, the third spiral of bossed beads; spiral cords separated by wide, finely spirally striate interspaces; suture with a spiral thread. *Aperture:* subcircular; anterior canal tubular, recurved; posterior canal a circular orifice

at the junction of the outer lip. *Color:* cream-white stained with brown, especially about midway on the teleoconch.

These triphorids are found at depths of from 3 to 6 m.

I. concors was described from the Straits of Malacca and has been recorded from Taiwan, Okinawa, and the Amami Islands (Kosuge, 1961a).

Iniforis hinuhinu Kay, new species. Fig. 48 H. Length, 7 mm; diameter, 2 mm. *Shell:* subulate, acuminate at the apex; with a tubular posterior canal; glossy, light brown, posterior canal white. *Spire:* protoconch of four and one-half conical, bicarinate whorls with minute axial threads; teleoconch of about 14 whorls, the abapical whorls inflated; suture indistinct. *Sculpture:* two rows of pearl-like beads on the apical whorls, three on the last whorl, the beads on raised keels and separate by about one-half their diameter; interspaces between the spirals with slightly oblique axial columns. *Aperture:* subcircular; anterior canal slightly recurved; posterior canal a closed tube which flares back. *Color:* glossy, light brown, apical whorls and posterior canal white; protoconch dark brown.

These triphorids occur at depths of 10 to 100 m.

Type locality: Kepuhi Point, Oahu, from sediments at a depth of 60 m, April, 1977. *Holotype:* Bernice P. Bishop Museum No. 9786. *Paratypes:* Australian Museum, British Museum (Natural History), U. S. National Museum.

The Hawaiian shells are similar in general style to those of *I. jousseaumei* (Hervier, 1897) from New Caledonia, but lack the third spiral of granules on the last whorl and dark brown band in the suture which distinguish the shells of *I. jousseaumei*. Derivation of name: *hinuhinu* Hawaiian — glossy. Descriptive of the glossy surface of the shells.

Iniforis ordinata Laseron, 1958b. Fig. 48 G. Length, 5.5 mm; diameter, 1 mm. *Shell:* elongate, straight-sided, slender; apex acuminate; anterior and posterior canals long and tubular; last whorl with two beaded spiral cords; cream. *Spire:* protoconch of three dark brown conical whorls, each set with two spiral keels cancellated by close-set, oblique axial threads; teleoconch of about 13 flat-sided whorls; suture shallow, distinct. *Sculpture:* two rows of beaded spiral cords with a fine spiral thread between, the abapical row with larger beads, and with an intercalary wavy thread between; suture with a spiral thread; base with a granular spiral cord. *Aperture:* circular; anterior and posterior canals long and tubular, encircled by concentric rings. *Color:* pale chestnut brown, granules white.

These triphorids are common in sediments at depths of 10 to 65 m.

I. ordinata was described from Christmas Island, Indian Ocean, from a depth of 100 fathoms.

Iniforis peleae (Baker and Spicer, 1935). Fig. 48 A. Length, 2.5 mm; diameter, 1 mm. *Shell:* elongate-conic, inflated; with two rows of beaded spiral threads; posterior canal long and tubular; white. *Spire:* protoconch of two whorls, the apical small and immersed, abapical convex and with curved axial ribs; teleoconch of seven inflated whorls; suture narrow, not defined. *Sculpture:* two rows of beaded spiral threads, the beads circular and separated spirally by one-quarter their diameter, wider than the suture and with spiral threads, and axially by a space about equal to their

diameter; suture with spiral threads; base with four smooth keels. *Aperture:* subcircular; posterior canal a circular hole on the back of the shell; anterior canal short, barely recurved. *Color:* white.

Shells are occasionally found in beach drift and in sediments to depths of 63 m.

I. peleae was described from Samoa.

Iniforis perfecta (Pease, 1871a). Fig. 48 I. Length, 7 mm; diameter, 2 mm. *Shell:* cylindrical-conic; posterior canal long and tubular; with two spiral rows of granules; upper granular spiral white, lower spiral dark brown. *Spire:* protoconch of at least one acuminate, conical, unicarinate brown whorl; teleoconch of about 12 rather convex whorls; suture indistinct. *Sculpture:* two prominent rows of granules, apical row of circular beads, abapical row of slightly smaller beads, the interspaces about one-half the diameter of the beads and with axial columns between the rows. *Aperture:* circular, deep; anterior canal slightly recurved; posterior canal closed, tubular. *Color:* translucent white, lower spiral on each whorl dark brown, posterior canal white.

These triphorids are rare, found at depths of about 10 m.

I. perfecta was described from Kauai.

Subfamily **Mastoniinae**

Six genera are presently recognized in this subfamily which differs from other sinistral triphorids primarily on the basis of the structure of the radula (Kosuge, 1966). The genera represented in Hawaiian waters are distinguished in the following key:

1. Shell with spirals of beads or granules 2
   Shell with spiral keels ..... *Viriola*
2. Shell conical, slightly convex to inflated 3
   Shell very narrow, straight-sided ..... *Inella*
3. Protoconch dome-shaped or immersed 4
   Protoconch acuminate, conical, carinate and with axial threads ..... *Mastonia*
4. Protoconch immersed, emerging as a single whorl from the beaded teleoconch ..... *Litharium*
   Protoconch blunt, dome-shaped, with axial ribs ..... *Cautor*

Cautor sp. cf. *intermissa* (Laseron, 1958b). Fig. 49 G. Length, 2.5 mm; diameter, 1 mm. *Shell:* obese to conic; with two beaded spirals on each whorl; straw with patches of brown between the granules. *Spire:* protoconch dome-shaped, of two and one-half white whorls, the apical partly immersed, the two abapical whorls with prominent axial ribs; teleoconch of about thirteen slightly inflated whorls; suture narrow. *Sculpture:* two spirals of hemispherical beads on each whorl, three on the last whorl, the apical row larger than the abapical row, the granules regularly arranged in axial columns. *Aperture:* subquadrate; posterior canal a notch; anterior canal tubular, recurved. *Color:* yellow with chocolate brown between the granules, apex white.

These triphorids are common in beach drift and found in sediments to depths of 10 m.

C. intermissa was described from Queensland and occurs in the Strait of Malacca, Philippines, and Loyalty Islands, and in Miocene and Holocene sediments in the Marshall Islands and Fiji (Ladd, 1972). The Hawaiian shells differ from the Australian shells in the number of whorls of the protoconch, which Laseron described as a single, tilted dome-shaped whorl, partly immersed in the summit.

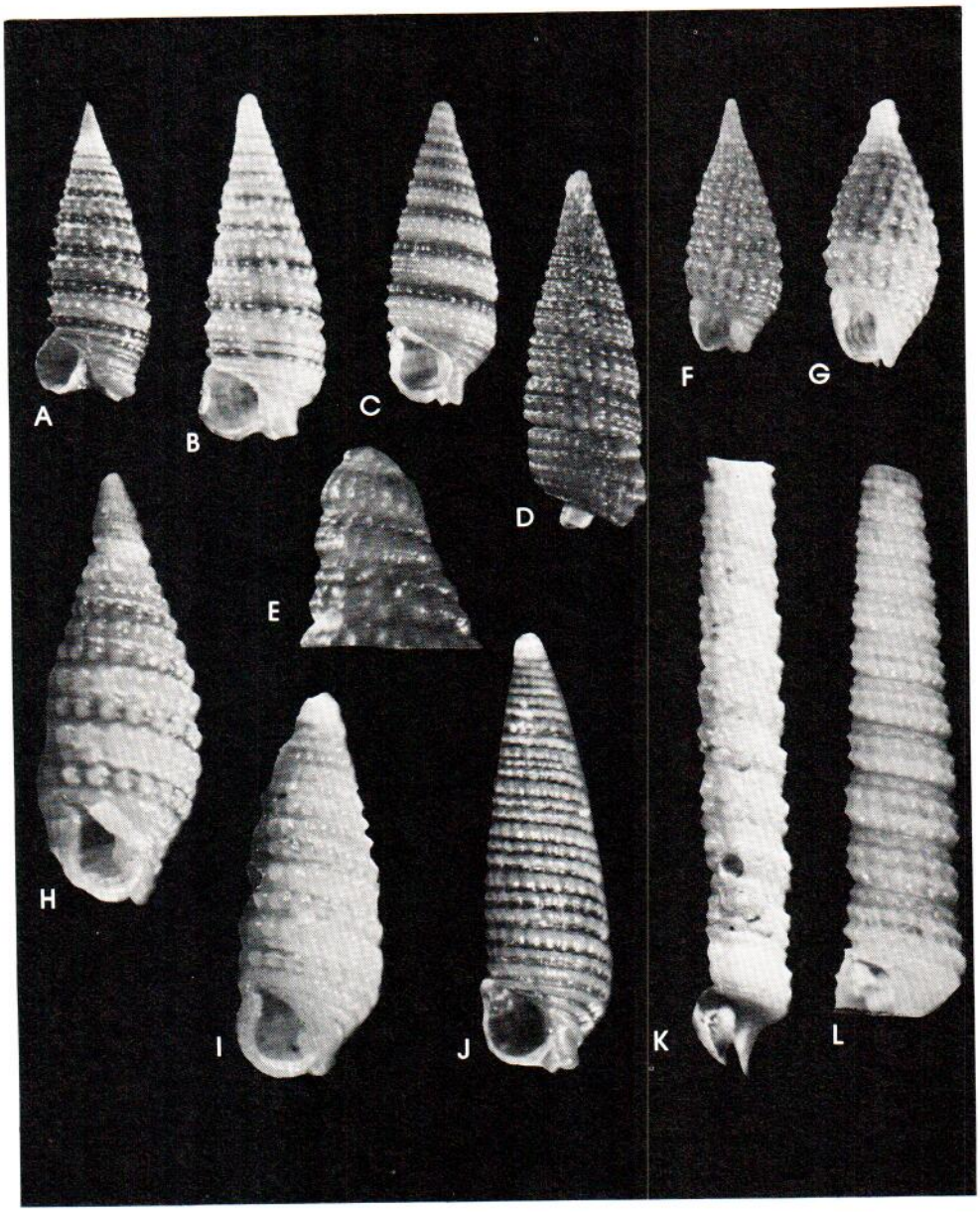


Figure 49.—A. *Mastonia cingulifera*, length 7 mm. B. *Litharium maculata*, length 6 mm. C. *Cautor similis*, length 4.5 mm. D. *C. similis*, brown form, length 5 mm. E. *C. similis*, protoconch. F. *Mastonia troglodytes*, length 3 mm. G. *Cautor intermissa*, length 2.5 mm. H. *C. minima*, length 3 mm. I. *Mastonia gracilis*, length 5 mm. J. *Litharium oceanida*, 4 mm. K, L. *Inella* spp., (K) 10 mm, (L) 12 mm.

Cautor minima (Pease, 1871a). Fig. 49 H. Length, 3 mm; diameter, 1 mm. *Shell:* conic; with two rows of granules on each whorl; lavender. *Spire:* protoconch of two and one-half partly immersed white whorls; teleoconch of about six whorls; suture shallow. *Sculpture:* two spiral rows of rounded beads on each whorl, the beads in the apical row of the last whorl larger than those of the abapical row; base with two obsoletely beaded cords. *Aperture:* ovate; anterior canal short, tubular, straight; sutural canal embayed. *Color:* lavender, apex white.

Shells are rarely found in beach drift.

C. minima was described from Kauai and Howland Island.

Cautor similis (Pease, 1871a). Fig 49 C, D, E. Length, 4.5 mm; diameter, 1.3 mm. *Shell:* conic-elongate, inflated; last whorl with three beaded spirals; the two apical spirals yellow, abapical row red-brown. *Spire:* protoconch dome-shaped, partly immersed at the summit, abapical whorl with axial ribs; teleoconch of seven or eight slightly convex whorls; suture deep, incised. *Sculpture:* three spirals of neat, rounded beads, the beads in the apical row separated by about half their diameter, those in the abapical rows nearly touching and faintly shelved; suture with a spiral thread; base with two spiral cords. *Aperture:* subovate; anterior canal closed; posterior canal a notch. *Color:* glossy, the two abapical spirals yellow, the adapical spiral red-brown, and with two brown spirals encircling the base; apical whorls white, protoconch brown. Some shells may be all brown.

Worn shells are common in beach drift; living animals are occasionally encountered under rocks in tide pools and shallow bays inshore on fringing reefs.

C. similis was described from the Hawaiian Islands, and also occurs in Borneo and the Philippines. The color variation exhibited by shells which are indistinguishable in terms of protoconch and sculpture of the teleoconch is unusual among the triphorids where color and pattern appear to be quite constant within a species. Brown shells of *C. similis* are distinguished from those of *Litharium oceanida* by the domed protoconch and discrete granules (in the shells of *L. oceanida* the granules are fused, especially on the last whorl).

Inella spp. Fig. 49 K, L. The shells of two species of *Inella* found in Hawaiian waters are figured. The exceedingly narrow, attenuate shells are fragile and subject to fragmentation, and are known only from depths of more than 60 m. Identification as to species is dependent on collection of intact shells.

Litharium maculata (Pease, 1871a). Figs. 47 C, 49 B. Length, 6 mm; diameter, 2 mm. *Shell:* conic-elongate; inflated; last whorl with three beaded spirals, the middle row threadlike; apical spiral yellow, the others brown and white. *Spire:* protoconch immersed, of one and one-half white whorls, followed by two or three white whorls, each with a single row of granules; teleoconch of about seven inflated whorls; suture wide and with a spiral thread. *Sculpture:* apical whorls with two, abapical whorls with three beaded spiral cords, the apical spiral the largest, the middle spiral linear; spirals of subcircular beads joined by threads and axial columns; interspaces between spirals smooth. *Aperture:* subcircular; anterior canal short, tubular, recurved; posterior canal a shallow notch. *Color:* apical row of beads yellow, abapical rows red-brown irregularly maculated with white, base with two brown spirals.

Beachworn shells are common in drift and to depths of about 15 m.

L. maculata was described from the Hawaiian Islands.

Litharium oceanida (Dall, 1924). Fig. 49 J. Length, 4 mm; diameter, 1.5 mm. *Shell:* conic-elongate, convex, apex blunt; last whorl with three beaded spirals; dark brown. *Spire:* protoconch immersed at the summit, appearing as a blunt cap at the apex of two whorls with blunt beading; teleoconch of nine or ten whorls; suture narrow, distinct and fairly deep. *Sculpture:* three spirals of small, regularly arranged beads, the rows of about equal size, the granules touching one another in the spiral, often almost fused in the apical row; the spirals separated by about one-eighth their diameter. *Aperture:* quadrate, anterior canal grooved and recurved; posterior canal a shallow sinus. *Color:* dark brown, the apex sometimes red-brown or straw-colored.

This is a common shallow-water triphorid in the Hawaiian Islands, found under rocks in tide pools, on reefs, and at depths to 10 m.

L. oceanida was described from the Hawaiian Islands. Shells are distinguished from the brown shells of *Cautor similis* by their smaller size, narrower outline, less distinct sculpture, and the immersed protoconch.

Mastonia cingulifera (Pease, 1861b). Fig. 49 A. Length, 7 mm; diameter, 2 mm. *Shell:* conic-elongate inflated; with two prominent beaded spirals and a threadlike middle spiral; yellow lineated with red-brown. *Spire:* protoconch acuminate, of four dark brown whorls, the apical smooth, remaining three unicarinate with fine axial ribs extending to the suture; teleoconch of ten inflated whorls; suture deep, wide. *Sculpture:* three beaded spirals of which the apical and abapical are prominent, the apical row of circular beads separated by shallow interspaces one-quarter the diameter of the beads and in the later whorls delineated abapically by a spiral thread; middle row threadlike; abapical row of small, spirally elongate beads; last whorl with four granular spirals, the rows progressively smaller and more obsoletely beaded; siphonal canal with a smooth cord bounding it. *Aperture:* subcircular; anterior canal not completely closed, short, sharply recurved; posterior canal a notch. *Color:* apical spiral red-brown, abapical yellow and base with three brown spirals; apical whorls white. *Animal:* exposed parts orange-red speckled with white.

This triphorid is both ubiquitous and abundant in Hawaiian waters. It is the most commonly occurring triphorid in shallow water, found in tide pools and shoreward of fringing reefs; it is less common in coral communities to depths of about 15 m. Shells are abundant in beach drift and are occasionally found in sediments to depths of 65 m.

M. cingulifera occurs throughout the Indo-West Pacific, from Mauritius (Viader, 1937) to New Caledonia and southern Japan (Kuroda and Habe, 1952), and has been reported from Holocene sediments from Enewetak, Marshall Islands and Saipan (Ladd, 1972).

Mastonia gracilis (Pease, 1871a). Fig. 49 I. Length, 4.0 mm; diameter, 1.0 mm. *Shell:* conic, inflated; last whorl with two granular spirals; apical spiral dark red with white granules, abapical spiral yellow. *Spire:* protoconch acuminate, of about four dark brown whorls, the apical mamillate, the others unicarinate with fine axial ribs extending on either side of the suture; teleoconch of six or seven inflated whorls; suture wide, deep. *Sculpture:* two granular spiral cords on the penultimate and apical whorls, three on the last whorl; spirals of prominent, circular beads separated by about

half their diameters and each spiral separated by its own diameter from the next; interspaces between spirals with recessed axial columns. *Aperture:* ovate; anterior canal short, tubular; posterior canal barely notched. *Color:* apical row of granules glistening yellow, abapical row of glistening white beads, the interspaces stained with red-brown.

Shells are uncommon in beach drift, more common in sediments at depths of from 10 to 60 m.

M. gracilis was described from the Hawaiian Islands. The shells are similar in shape and sculpture to those of *M. monilifera* Hinds, 1843, described from the Strait of Malacca and known also from Japan (Kosuge, 1962a), but the smaller size and dark red staining on the apical row of granules are distinctive. The holotype of *M. monilifera* is 5 mm in length and the shell is predominantly yellow, merely picked with red-brown between the granules on the abapical spiral.

Mastonia troglodytes (Hervier, 1897). Fig. 49 F. Length, 3 mm; diameter, 1 mm. *Shell:* ovate, medially inflated; with two spiral granules on each whorl; yellow with chestnut brown between the granules. *Spire:* protoconch of four and one-half acuminate, conical whorls, the apical one and one-half whorls smooth, the others bicarinate, carinate whorls with axial threads; remaining whorls about six; suture indistinguishable. *Sculpture:* two spiral cords of granules with a third threadlike row intercalated on the last whorl; granules rounded on the upper whorls, axially elongate on the last whorl where the apical row is largest; base with two spiral keels. *Aperture:* oval; anterior canal short and recurved; no posterior canal. *Color:* yellow with chestnut brown staining the interspaces between the granules.

These triphorids are common in beach drift and in sediments to depths of 10 m.

M. troglodytes was described from Lifu.

Viriola abbotti (Baker and Spicer, 1935). Fig. 50 E. Length, 8 mm; diameter, 2 mm. *Shell:* elongate-conic, convex, solid; with spiral keels; dove-gray. *Spire:* protoconch acuminate, of three or four dark brown whorls, the apical smooth, the others unicarinate and with axial threads; teleoconch of about 11 somewhat inflated whorls; suture wide, shallow. *Sculpture:* apical whorls with two minutely beaded keels and axial threads, the keels becoming smooth and the axial threads disappearing on the later whorls where there are three subequal, smooth, sharp keels on each whorl, the middle keel weakest; interspaces and suture finely spirally striate; base with three spiral cords. *Aperture:* subcircular; outer lip enclosing the short, closed, recurved anterior canal; posterior canal a shallow notch. *Color:* dove-gray, apical whorls white.

These shells are common in beach drift and to depths of 50 m.

V. abbotti was described from Samoa.

Viriola bayani Jousseaume, 1884. Fig. 50 J. Length, 14 mm; diameter, 2.5 mm. *Shell:* elongate-conic, slender, flat-sided; with spiral keels joined by short axial threads; brown. *Spire:* protoconch of four whorls, bicarinate and with axial threads; teleoconch of about 18 whorls; suture indistinct, oblique. *Sculpture:* spiral sculpture of three keels on each whorl, the abapical keel the largest, the middle keel smallest; with axial threads between the keels producing a pitted appearance; base with a peripheral keel and two abapical cords; apical whorls with faintly beaded keels. *Aperture:* ovate,

outer lip completely enclosing the prominent, recurved anterior canal; posterior canal a narrow slit. *Color:* brown.

These triphorids are common at depths of 60 to 100 m.

V. bayani was described from New Caledonia. These elegant shells are distinguished from those of *V. corrugata* (Hinds, 1843) by their slender shape and from those of *V. excelsior* (Melvill and Standen, 1899) by the axial pitting between the keels.

Viriola bilix (Hinds, 1843). Fig. 50 F. Length, 7 mm; diameter, 1.5 mm. *Shell:* elongate-conic, slender; with spiral keels, the abapical keel granulated; white flamed with brown. *Spire:* protoconch of four and one-half acuminate whorls, the abapical whorls bicarinate, apical whorls unicarinate, all with axial threads; teleoconch of 13 whorls; suture shallow, slightly oblique. *Sculpture:* three spiral keels and a sutural thread; abapical keel the largest, protruding and slightly granulated; remaining keels narrow, undulating; interspaces smooth; apical whorls with distinctly beaded keels. *Aperture:* subcircular, deep outer lip completely enclosing the short, recurved anterior canal; posterior canal a simple notch. *Color:* white maculated with dark brown.

These shells are common at depths of 60 to 100 m.

V. bilix was described from the Strait of Malacca.

Viriola cancellata Hinds, 1843. Fig. 50 D. Length, 6 mm; diameter, 2 mm. *Shell:* conic-elongate, slender, straight-sided; with spiral keels; yellow-white, interspaces axially striated with chestnut. *Spire:* protoconch acuminate, of four dark brown whorls, apical whorl smooth, remaining whorls bicarinate and with axial threads; teleoconch of 10 whorls; suture shallow, distinct. *Sculpture:* two prominent spiral keels with a smaller beaded spiral thread between, interspaces smooth; base with a granular keel and two cords. *Aperture:* ovate; posterior canal shallow, notched. *Color:* yellow-brown, the middle spiral with yellow granules and brown interspaces.

This triphorid is uncommon, found at depths of 20 to 28 m.

V. cancellata was described from the Strait of Malacca and has been reported from Okinawa and the Amami Islands (Kosuge, 1961b).

Viriola elongata (Laseron, 1958b). Fig. 50 H. Length, 14 mm; diameter, 3 mm. *Shell:* elongate-conic, slender; with three spiral keels, the apical and abapical keels slightly granular; cream to light brown. *Spire:* protoconch of four and one-half acuminate whorls, dark brown, abapical whorls bicarinate, others unicarinate, all with axial threads; teleoconch of about 14 whorls; suture shallow, barely distinct. *Sculpture:* three keels of varying sizes, the apical and abapical the largest with elongate granules projecting sharply; interspaces finely striate; sutural thread present; last whorl with an extra keel; base with a single cord. *Aperture:* nearly circular, entirely enclosing a long, oblique anterior canal; posterior canal a narrow notch.

These triphorids are common at depths of about 60 m.

V. elongata was described from the Torres Strait and Masthead Reef, Australia. The Hawaiian shells differ from Laseron's type in their richer color, but the type specimens are beachworn.

Viriola fallax Kay, new species. Fig. 50 C, G. Length, 3.75 mm; diameter, 1 mm (holotype). *Shell:* conic-elongate; spirally keeled; white maculated with light

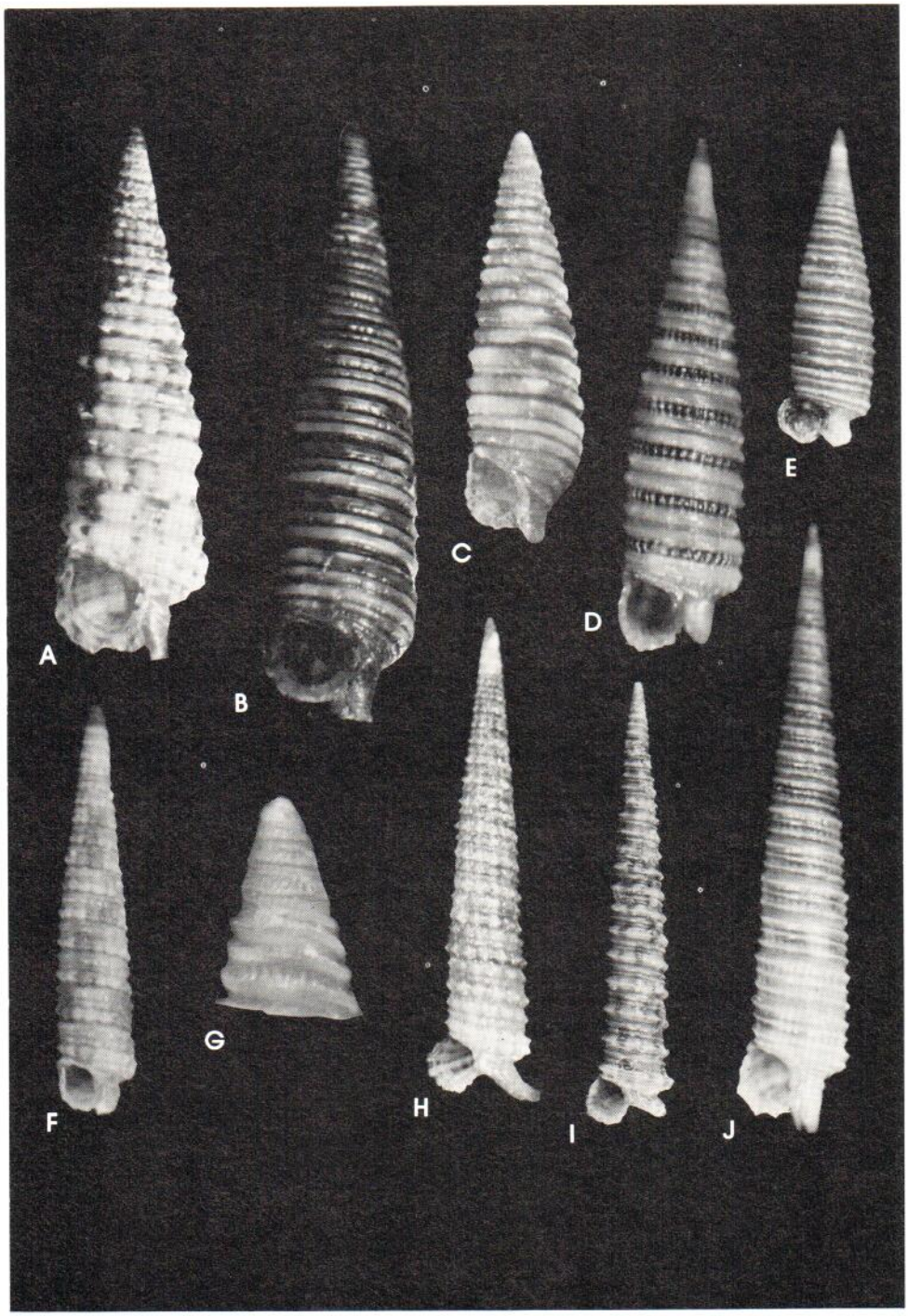


Figure 50.—**Triphoridae.** A. *Viriola flammulata*, length 15 mm. B. *V. incisa*, length 12 mm. C. *V. fallax*, length 3.75 mm (holotype). D. *V. cancellata*, length 6 mm. E. *V. abbotti*, length 8 mm. F. *V. bilix*, length 7 mm. G. *V. fallax*, protoconch. H. *V. elongata*, length 14 mm. I. *V. pagoda*, length 25 mm. J. *V. bayani*, length 14 mm.

brown. *Spire:* protoconch acuminate, of four whorls, the apical smooth, the others unicarinate and with axial threads; teleoconch of straight-sided whorls; suture shallow. *Sculpture:* three spiral keels on each whorl, four on the last, the interspaces of lesser diameter than the keels and smooth abapically but with incipient axial threads on the apical whorls. *Aperture:* subovate; posterior canal a notch; anterior canal tubular, barely recurved. *Color:* white, maculated with light brown.

These triphorids are found at depths of 10 to 60 m.

Type locality: Milolii, Hawaii, in sediments at a depth of 10 m. *Holotype:* B. P. Bishop Museum No. 9798. *Paratype:* United States National Museum.

Shells of *V. fallax* superficially resemble those of *V. incisa* but are smaller (length 3.75 vs. 11 mm), of a lighter brown color, have incipient axial threads present between the spiral keels, and have a distinctly unicarinate protoconch. These shells are distinguished from other species of *Viriola,* such as *V. trilirata* (Deshayes, 1863) from Réunion, by the lack of any indication of granules on the spiral keels (the middle keel in shells of *V. trilirata* tend to be distinctly granular). Derivation of name: *fallax,* Latin adj. — false. Refers to superficial resemblance to *V. incisa.*

Viriola flammulata (Pease, 1861b). Fig. 50 A. (Synonyms: *?Cerithium gracilentum* Mighels, 1845; *Triforis marmorata* Pease ms., Martens and Langkavel, 1871.) Length, 15 mm; diameter, 4 mm. *Shell:* conic-elongate; turriculate; spirally keeled; white with light brown flamelike markings. *Spire:* protoconch acuminate, of four dark brown whorls, apical whorl smooth, next whorl unicarinate, remaining whorls bicarinate, carinate whorls with axial threads; teleoconch of about 18 whorls; suture wide, shallow. *Sculpture:* three spiral keels, the middle keel the smallest, the apical and abapical keels thick and shelflike, the abapical sometimes beaded; interspaces smooth; suture with a spiral thread; base of last whorl with two smooth spiral threads. *Aperture:* subovate, outer lip not recurving to columella; posterior canal barely notched. *Color:* white with axially oriented splashes of brown.

These triphorids are common in shallow water, often found under rocks with *V. incisa* shoreward on fringing reefs; and occur in sediments to depths of 100 m.

V. flammulata was described from the Hawaiian Islands. It has also been reported from Mauritius (Viader, 1937), and occurs in the Amami Islands (as *Viriola kanamurai* Kosuge 1961b, Pl. 22, Fig. 10, non *V. flammulata* Kosuge 1961b, Pl. 22, Fig. 3), and Samoa (as *Triphora granti* Baker and Spicer, 1935). The shells are distinguished from those of *V. elegans* (Hinds, 1843) by the smooth keels and interspaces.

Viriola incisa (Pease, 1861b). Fig. 50 B. Length, 12 mm; diameter, 3 mm. *Shell:* conic-elongate, turriculate; with three spiral keels of the same size; dark brown mottled with light brown. *Spire:* protoconch acuminate, of three to five dark brown whorls, the apical whorl smooth, the others unicarinate and with axial threads, the abapical whorl prominently bicarinate; teleoconch of straight-sided whorls; suture shallow. *Sculpture:* three spiral keels of about the same size on each whorl, the interspaces smooth or marked with fine striae. *Aperture:* subovate; posterior canal nearly closed, circular; anterior canal tubular, recurved. *Color:* brown marbled with varying tones of lighter and darker brown.

These triphorids are common in shallow water, on the undersurfaces of rocks on reefs and in shallow bays; shells have been dredged from depths of 8 to 50 m.

V. incisa was described from the Hawaiian Islands, but ranges throughout the Indo-West Pacific from the Cocos-Keeling Islands, to the Philippines, southern Japan, Amami Islands (Kosuge, 1961b), Micronesia, and Polynesia. In sculpture and color the teleoconch is indistinguishable from that of *V. fallax* but the shells of *V. incisa* are consistently larger and the protoconch is larger and prominently bicarinate.

Viriola pagoda (Hinds, 1843). Fig. 50 I. Length, 25 mm; diameter, 4 mm. *Shell:* conic-elongate, solid; with three spiral keels, the abapical keel overhanging the others; white flamed with brown. *Spire:* protoconch unknown, teleoconch of about 26 whorls; suture indistinct. *Sculpture:* three smooth keels on each whorl, the apical keels small, the abapical keel large and hanging over the keels on the next whorl, resulting in a pagodalike shape; interspaces between keels wide and smooth; sutural thread weakly developed. *Aperture:* subcircular; outer lip flared and fluted, nearly enclosing the anterior canal; posterior canal a simple notch. *Color:* white flamed with brown.

These triphorids are rare, found in rubble at depths of 6 m.

This species was described from the Philippine Islands and has been reported from the Amami Islands (Kosuge, 1961b).

Subfamily **Triphorinae**

The subfamily Triphorinae contains a single genus, *Triphora*, in which the shells are sinistral, high-spired and usually slender, with the anterior canal a narrow groove and the posterior canal a narrow slit (Kosuge, 1966). The sculpture consists of three granular spirals on each whorl. The protoconch in all the Hawaiian species is conic, acuminate, carinate, and with axial threads overriding the carina.

Triphora bicolor (Pease, 1868b). Fig. 51 A. (Synonyms: *Triphoris alternata* Pease, 1861b, non C. B. Adams, 1852; *Mastonia harperi* Jousseaume, 1884.) Length, 7.5 mm; diameter, 2 mm. *Shell:* conic-inflated; last whorl with three beaded spiral threads; apical and abapical spirals yellow, middle row brown. *Spire:* protoconch acuminate, of four light brown whorls, the apical smooth, the others carinated with two spiral keels overrun by axial threads; teleoconch of eight inflated whorls; suture wide, shallow. *Sculpture:* three beaded spirals on each whorl, the apical row with large circular, close-set beads, the abapical row with hemispherical bosses and axial columns, middle row with smaller beads; base with two smooth or obsoletely beaded spirals. *Aperture:* anterior canal short, recurved; posterior canal a narrow slit. *Color:* apical spiral yellow, abapical yellow-brown, middle row and suture dark brown; apical whorls white.

These triphorids are common in tide pools and in shallow water on fringing reefs.

T. bicolor was described from the Hawaiian Islands.

Triphora chrysolitha Kay, new species. Fig. 51 B, G, H. Length, 4.5 mm; diameter, 1 mm. *Shell:* subulate, conic; with three beaded spiral cords on the last whorl; orange-brown, a white spiral on the penultimate whorl. *Spire:* protoconch of five and one-half acuminate, conical whorls, apical two whorls smooth, the others strongly unicarinate and overridden with axial threads; teleoconch of nine whorls;

suture distinct, deep, slightly oblique. *Sculpture:* three beaded spiral cords on the last whorl, apical row of close-set circular beads, others of smaller, spirally elongate granules; middle spiral threadlike or absent apical of the penultimate whorl; interspaces between spirals about the same width as the spirals, marked by the swollen bases of

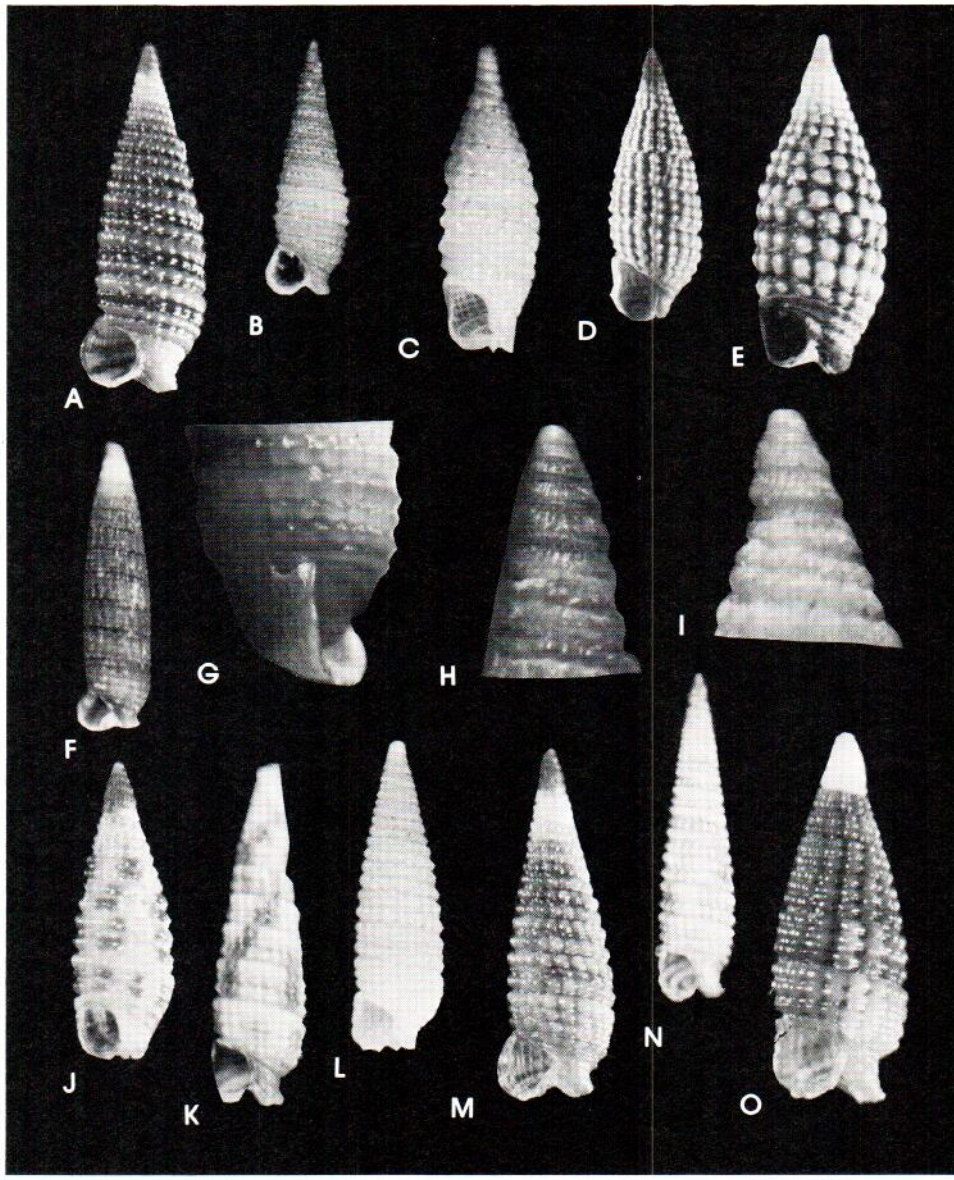


Figure 51.—**Triphoridae.** A. *Triphora bicolor*, length 7 mm. B. *T. chrysolitha*, length 4.5 mm (holotype). C. *T. lutea*, length 5 mm. D. *T. laddi*, length 3.5 mm (holotype). E. *T. triticea*, length 3 mm. F. *T. truncis*, length 5 mm. G, H. *T. chrysolitha*, sculpture (G) and protoconch (H). I. *T. laddi*, protoconch. J. *T. coralina*, length 3.5 mm. K. *T. tessellata*, length 4 mm. L. *T. pallida*, length 5 mm. M, N. *T. tuberculata*, (M) shallow water form, length 6 mm; (N) deep water form, length 7 mm. O. *T. isaotakii*, length 12 mm.

the granules; base with two spiral cords. *Aperture:* subcircular; outer lip not enclosing anterior canal which is short, slightly recurved; posterior canal an almost entirely enclosed, hooklike notch. *Color:* glossy, orange-brown, apical spiral on penultimate whorl white; protoconch dark brown.

These triphorids are common at depths of 10 to 60 m.

Type locality: Makaha, Oahu, from sediments at a depth of 60 m. *Holotype:* B. P. Bishop Museum No. 9788. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells perhaps most closely resemble those of *Triphora issa* Jousseaume, 1884, which have a similar color pattern, but the protoconch in that species is immersed. Derivation of name: *chryso,* Latin — gem; *litho,* Latin — stone. Refers to the orange-brown, gemlike granules.

Triphora coralina (Laseron, 1958b). Fig. 51 J. Length, 3.5 mm; diameter, 1 mm. *Shell:* conic, medially inflated, acuminate at the apex; with three granular spirals on the last whorl; white splashed with brown. *Spire:* protoconch acuminate, of five whorls, apical whorls smooth, abapical whorls unicarinate, then bicarinate, with fine axial threads; teleoconch of seven convex whorls; suture shallow, oblique. *Sculpture:* two equal rows of round beads on the apical whorls, about 18 to the whorl, close together and rising from defined keels; a small median row of beads developing on the abapical whorls; base with two spiral cords. *Aperture:* subcircular; outer lip barely enclosing the anterior canal which is short and recurved; posterior canal a shallow notch. *Color:* white, with irregular brown patches, last whorl with the apical spiral white; protoconch dark brown.

These triphorids are found at depths of about 50 m.

T. coralina was described from Christmas Island, Indian Ocean, where the shells were dredged from depths of 100 fathoms.

Triphora earlei Kay, new species. Fig. 52 D, E. Length, 11 mm; diameter, 2 mm. *Shell:* elongate-conic, turreted; with three rows of granular spirals on the last whorl; cream to brown, apical spiral darker brown than the others. *Spire:* protoconch slender, acuminate, with three and one-half bicarinate whorls overrun by axial threads; teleoconch of 16 whorls; suture distinct, wide, slightly oblique and with a sutural thread. *Sculpture:* three rows of close-set granules, the apical row with pearl-like beads, the other rows with bossed granules; granules about one-eighth their diameter apart and joined by axial columns. *Aperture:* subquadrate, outer lip not enclosing the anterior canal which is slightly recurved; posterior canal a shallow notch. *Color:* live-collected shells are rich brown, the apical spiral on each whorl darker than the others; dead shells are cream to light brown except for the darker brown apical spiral.

These triphorids have been found at depths of from 10 to 100 m.

Type locality: Kepuhi Point, Oahu, from a depth of 33 m. *Holotype:* B. P. Bishop Museum No. 9794. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The tall spire and distinctive color pattern distinguish these shells from those of *T. incolumnis* Melvill, 1918, from the Persian Gulf, *T. kawamurai* Kosuge, 1962a, from Japan, and *T. coetviensis* Melvill, 1909, from Coetvy Island. This species is named for John Earle whose interest in triphorids has resulted in the discovery of several new species.

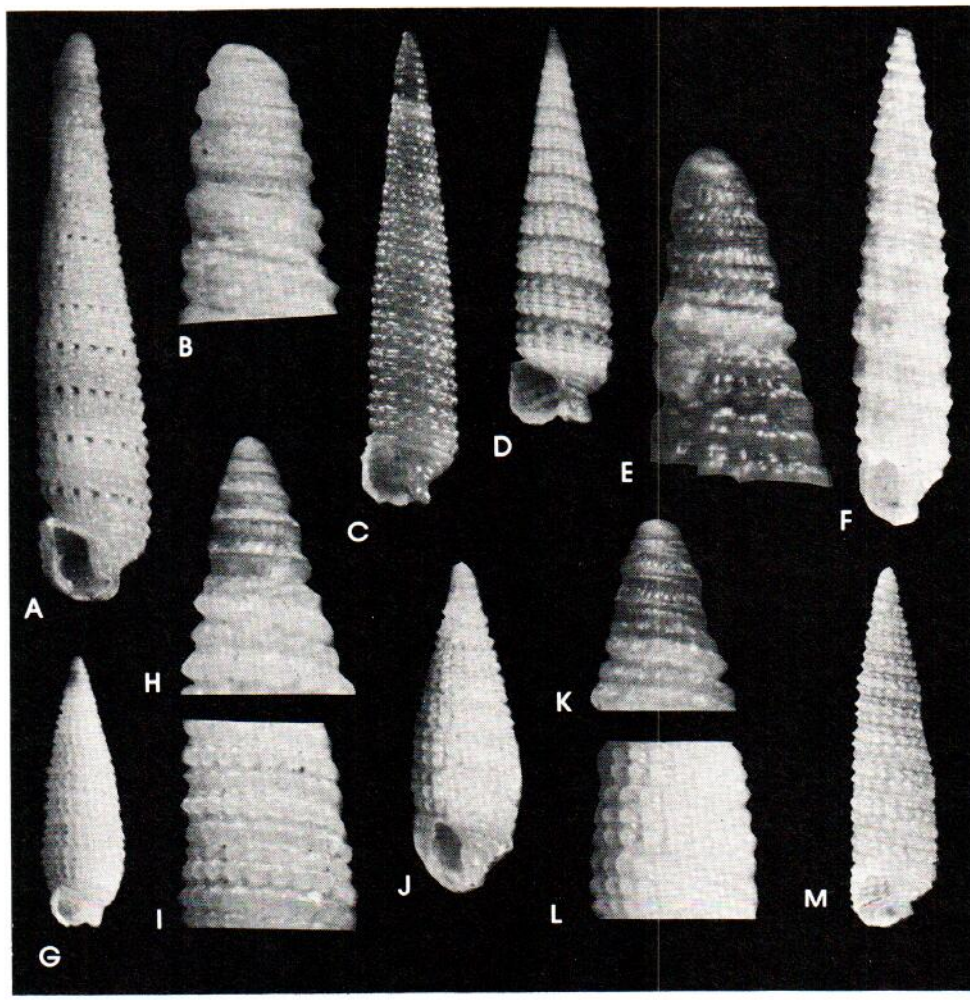


Figure 52.—**Triphoridae.** A. *Triphora thaanumi*, length 5.75 mm (holotype). B. *T. thaanumi*, protoconch. C. *T. peasi*, length 6 mm. D. *T. earlei*, length 11 mm (holotype). E. *T. earlei*, protoconch. F. *T. keiki*, length 6 mm (holotype). G. *T. rufotincta*, length 5 mm. H, I. *T. rufotincta*, protoconch and sculpture. J. *T. pustulosa*, length 4 mm. K, L. *T. pustulosa*, protoconch and sculpture. M. *T. tubularis*, length 7 mm.

Triphora isaotakii (Kosuge, 1962a). Fig. 51 O. Length, 12 mm; diameter, 4 mm. *Shell:* conic, stout; with three granular spirals on the last whorl; olive-brown, apex white. *Spire:* protoconch of four whorls, unicarinate and with axial threads; teleoconch of 11 rather straight-sided whorls; suture distinct, oblique, with a fine sutural thread. *Sculpture:* three prominent rows of granules with strong axial and spiral connections producing a latticelike effect; granules prominent, about equal in size on each row, spirally elongate and apart by about one-third their diameter; base with two cords. *Aperture:* ovate; outer lip nearly enclosing the siphonal canal, which is long and recurved; outer lip distinctly fluted; posterior sinus a notch.

These triphorids are found at depths of about 20 m.

T. isaotakii was described from the Amami Islands.

Triphora keiki Kay, new species. Fig. 52 F. Length, 6 mm; diameter, 0.75 mm. *Shell:* very slender, conic; with three microscopic granular spirals; glossy, cream flamed with brown. *Spire:* protoconch acuminate, of five whorls, the apical two whorls apparently smooth, the others bicarinate, overrun with axial threads; teleoconch of 12 whorls, the abapical portion of each whorl projecting slightly over the adjacent whorl resulting in a somewhat turreted effect; suture indistinct, oblique. *Sculpture:* three rows of minutely beaded spirals on each whorl, the apical row recessed, abapical rows projecting; beads circular, separated by about their own diameter; abapical rows joined by slightly recessed axial columns; base with two spiral cords. *Aperture:* subquadrate; outer lip not enclosing the moderately long, recurved anterior canal; posterior canal a notch. *Color:* glossy, translucent cream with axial streaks of red-brown.

These triphorids are uncommon, found at depths of 33 m.

Type locality: Kepuhi Point, Oahu, from sediments at a depth of 33 m. *Holotype:* B. P. Bishop Museum No. 9790. *Paratype:* B. P. Bishop Museum.

The small size, minutely beaded spirals, oblique suture and overhanging whorls distinguish these shells from those of other triphorids. The shape of the shell is like that of *Inella*, but the protoconch is that of *Triphora*. Derivation of name: *keiki*, Hawaiian — child. Refers to the small size and sculpture of these shells.

Triphora laddi, new species. Fig. 51 D, I. Length, 3.5 mm; diameter, 1.25 mm. *Shell:* conic-ovate, inflated; with three granular spirals on the last whorl; lavender. *Spire:* protoconch acuminate, of three and one-half or four dark brown whorls, unicarinate and with axial threads; teleoconch of four convex, inflated whorls; suture shallow, distinct. *Sculpture:* three granular spirals on the whorls, the granules hemispherical, nearly touching one another and axially joined by oblique columns; periphery of last whorl with a fourth spiral and with one cord on the base; suture with a spiral thread. *Aperture:* subcircular; outer lip not enclosing the short, recurved anterior canal; posterior canal a simple notch. *Color:* protoconch dark brown, remainder of shell lavender.

These triphorids are common in tide pools and shallow bays, and shells are frequent in beach drift.

Type locality: Off Waikiki from a depth of 10 to 24 m. *Holotype:* Bernice P. Bishop Museum No. 9800. *Paratype:* U. S. National Museum.

The shells of *T. laddi* resemble those of *T. lucidulus* (Hervier, 1897) and *T. rossiteri* (Jousseaume, 1884) from New Caledonia in shape, sculpture, and the unicarinate protoconch, but the Hawaiian shells are smaller (the New Caledonian shells are 4 to 5 mm in length), and the lavender color is distinctive. The species is named for Dr. Harry S. Ladd of the U. S. Geological Survey, U. S. National Museum, who has contributed immeasurably to our knowledge of fossil marine mollusks in the Pacific.

Triphora lutea (Kosuge, 1962b). Fig. 51 C. Length, 5 to 8 mm; diameter, 1.25 mm. *Shell:* ovate to conic, inflated, attenuate at the apex; with three granular spirals on the last whorl; orange-yellow. *Spire:* protoconch of three and one-half convex whorls, bicarinate and with axial threads; teleoconch of 10 inflated whorls; suture shallow, with a sutural thread. *Sculpture:* three granular spirals on the last whorl, the apical spiral becoming threadlike on the apical whorls; granules elongate, connected by shallow axial columns; base with a fourth spiral and two cords. *Aperture:* elongate,

constricted, outer lip not enclosing the anterior canal which is a more or less open tube; posterior canal an excavated notch. *Color:* orange-yellow, worn shells white.

These shells are found at depths of about 6 m. There appear to be two shell forms, one with a short, inflated shape, the other with an elongate conic shape.

T. lutea was described from the Amami Islands.

Triphora pallida (Pease, 1871a). Fig. 51 L. Length, 5 mm; diameter, 1.5 mm. *Shell:* conic-elongate; sides gently convex, last whorl with three beaded spiral threads; white. *Spire:* protoconch acuminate, white, of four whorls, the apical smooth, the others unicarinate with axial threads; teleoconch of ten gently convex whorls; suture obscure. *Sculpture:* apical whorls with two, abapical whorls with three rows of circular beads barely separated by interspaces, the middle spiral the smallest; base with two small, obscurely beaded cords. *Aperture:* subquadrate; anterior canal short, recurved; posterior canal a short, narrow notch. *Color:* white.

Worn shells are common in beach drift; living animals are occasionally found under rocks in tide pools and are common at depths to 50 m.

This species was described from the Hawaiian Islands. It also occurs in the Philippines and Micronesia and in Holocene sediments in the Marshall Islands (Ladd, 1972). *T. albomicra* (Laseron, 1958b) from Queensland, Australia, is a synonym.

Triphora peasi (Jousseaume, 1884). Figs. 47 A, B; 52 C. (Synonym: *Triphoris affinis* Pease, 1861b, non *affinis* Hinds, 1843.) Length, 6 mm; diameter, 1.5 mm. *Shell:* elongate-conic, slender, straight-sided; last whorl with three beaded spirals; yellow-brown. *Spire:* protoconch acuminate, dark brown, of seven whorls, the two apical whorls mamillate, the next two unicarinate, remaining whorls bicarinate, carinate whorls with axial threads; teleoconch of ten or twelve straight-sided whorls; suture shallow. *Sculpture:* three beaded spiral cords, the beads subcircular, bossed, close-set and joined by axial columns; base with one or two obsoletely beaded or smooth threads. *Aperture:* ovate; anterior canal short; barely recurved; posterior canal a shallow notch. *Color:* yellow-brown to buff, apical whorls white.

Shells are occasionally found in beach drift and are common in sediments to depths of 65 m. The shells are variable in shape, ranging from a more inflated form in shallow water to a slender form in deep water.

T. peasi was described from the Hawaiian Islands. The shells are similar to those of *T. verrucosa* (Adams and Reeve, 1848) described from the "China Seas," but in *T. verrucosa* the whorls of the protoconch are unicarinate.

Triphora pustulosa (Pease, 1871a). Fig. 52 J-L. Length, 4 mm; diameter, 1 mm. *Shell:* elongate-cylindrical; last whorl with three beaded spirals; yellow-brown, interstices between the granules red-brown. *Spire:* protoconch acuminate, of five light brown, conical whorls, the apical smooth, the others unicarinate with distinct, fine, vertical axial threads; teleoconch of about seven whorls; suture shallow, distinct. *Sculpture:* apical whorls with two, abapical whorls with three, beaded spirals, the granules rounded and distinct, separated by interspaces of lesser diameter and regularly arranged in axial columns; suture with a spiral thread; base with an obsoletely beaded thread and a spiral cord. *Aperture:* ovate; outer lip without a sinus; anterior canal short and recurved. *Color:* yellow-brown, the keels between the granules red-brown producing the pustulated effect noted by Pease (1871a).

Shells are occasionally found in beach drift and in sediments to depths of 30 m.

T. pustulosa was described from the Hawaiian Islands. These triphorids are distinguished from other yellow shells picked with red-brown by their more conical shape, three spirals on the last whorl, and acuminate brown protoconch.

Triphora rufotincta (Kosuge, 1963a). Fig. 52 G-I. Length, 5 mm; diameter, 1.25 mm. *Shell:* conic-ovate; apex attenuate; with three granular spirals on the last whorl; yellow-brown, abapical spiral lightly tinted with red-brown. *Spire:* protoconch of five whorls, unicarinate with strong, straight axial ribs; teleoconch of about 10 slightly convex whorls; suture shallow, oblique. *Sculpture:* three rows of small, circular granules on each whorl; apical and abapical rows better developed than the middle row which is threadlike on the apical whorls; base with three cords. *Aperture:* ovate; outer lip enclosing the anterior canal; anterior canal short, recurved; posterior canal an almost completely closed orifice. *Color:* yellow-brown, the abapical spiral with red-brown on the posterior edge of the granules; protoconch horn colored.

These shells are common in sediments at depths of about 60 m.

T. rufotincta was described from the Amami Islands.

Triphora tessellata (Kosuge, 1963a). Fig. 51 K. Length, 4 mm; diameter, 1 mm. *Shell:* conic-elongate, barely inflated; last whorl with three beaded spirals; white blotched with brown. *Spire:* protoconch acuminate, of five whorls, the apical smooth, abapical whorls bicarinate and overrun by axial threads; teleoconch of eight slightly inflated whorls; suture distinct, channeled. *Sculpture:* three beaded spirals on each whorl, the apical and abapical rows of larger beads than the middle spiral which becomes threadlike on the apical whorls; beads circular and close-set, less than one-quarter their own diameter apart. *Aperture:* subquadrate, outer lip not enclosing the anterior canal which is recurved; posterior canal a simple notch. *Color:* white, blotched with red-brown arranged axially in linear series; siphonal canal and base brown; protoconch dark brown.

These triphorids are uncommon at depths of about 6 m.

T. tessellata was described from the Amami Islands. The shells are distinguished from those of *T. coralina* by the more slender outline, more closely set beads, and the axially oriented brown blotches.

Triphora thaanumi Kay, new species. Fig. 52 A, B. Length, 5.75 mm; diameter, 1 mm (holotype). *Shell:* slender, conic, with nearly straight sides; whorls with three weakly beaded spiral cords; honey yellow, middle spiral picked with red-brown. *Spire:* protoconch acuminate, large (length, 0.5 mm; diameter of base 0.4 mm), of three and one-half whorls, the apical smooth, the others strongly bicarinate and overridden by axial threads; teleoconch of about 13 rather straight-sided whorls; suture shallow, narrowly channeled. *Sculpture:* three equally developed rows of rather weakly defined granules on each whorl, the granules separated one from another by less than half their own diameter, interspaces between spirals with weak, recessed axial columns. *Aperture:* subcircular; anterior canal nearly closed, abruptly short; posterior canal a shallow notch. *Color:* honey yellow, the middle spiral of each whorl picked with red-brown between the granules; protoconch red-brown.

These triphorids are fairly common at depths of from 6 to 30 m.

Type locality: Kahe Point, Oahu, at a depth of 6.5 m, April, 1977. *Holotype:* Bernice P. Bishop Museum No. 9796. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

These Hawaiian shells are distinguished by their small size, neat sculpture, straight-sided whorls, and relatively large protoconch. They are distinguished from the shells of *T. rufotincta* (Kosuge, 1963a) by the tall columnar form and red-brown staining on the middle spiral, and from other similarly colored shells such as *Mastonia servaini* Jousseaume, 1884 and *T. rutilans* Hervier, 1897 from the Red Sea and New Caledonia, respectively, by shape and subtle differences in color pattern. This species is named for the late Ditlev Thaanum, dean of Hawaiian marine malacology, who was the first to dredge specimens.

Triphora triticea Pease, 1861b. Fig. 51 E. Length, 3 mm; diameter, 1 mm. *Shell:* spindle-shaped; last whorl with three granular spirals; dark brown. *Spire:* protoconch acuminate, of three and one-half brown whorls, the apical smooth, the abapical whorls carinate and with axial threads; teleoconch of three or four inflated whorls; suture shallow and indistinct. *Sculpture:* apical whorls with two, last whorl with three spirals of prominent, circular beads joined by axial pillars; last whorl with two obsoletely beaded cords. *Aperture:* subcircular, small; anterior canal closed, short, recurved; posterior canal almost tubular but free on the outer lip; outer lip reflected. *Color:* dark brown or black, granules blue-white abapically; protoconch and outer lip light brown; apical whorls white.

This is a common shallow water species found under rocks in tide pools and bays shoreward of fringing reefs.

T. triticea was described from the Hawaiian Islands; it has also been recorded from Christmas Island, Indian Ocean (Smith, 1909; Tomlin, 1935a) and is found in the Philippines, Okinawa, and the Amami Islands (Kosuge, 1963b, as *Mastonia crassula* von Martens, 1880)).

Triphora truncis (Laseron, 1958b). Fig. 51 F. Length, 5 mm; diameter, 1 mm. *Shell:* cylindrical, apex tapering; with three granular spirals on the last whorl; dark brown, apex white. *Spire:* protoconch not known; teleoconch of about 10 straight-sided whorls; suture distinct, oblique. *Sculpture:* last whorl with three rows of rounded granules, other whorls with two and a median thread; granules small, rounded, and very close set. *Aperture:* ovate; outer lip not enclosing the anterior canal which is short, recurved; posterior sinus a deep, narrow slit. *Color:* dark brown, apex white.

These triphorids have been collected at depths of 50 to 60 m.

T. truncis was described from the Capricorn Group, off Cairns, and from Low Isles on the Great Barrier Reef, Australia.

Triphora tuberculata (Pease, 1871a). Fig. 51 M, N. Length, 6 mm; diameter, 2 mm. *Shell:* subulate-conic; tapering apically and narrowed at the base; last whorl with three beaded spirals; apical row of beads light gray, abapical spirals gray-brown maculated with light gray. *Spire:* protoconch acuminate, of four brown whorls, the apical whorl smooth, the others carinated by two spiral keels joined by axial threads; teleoconch of about ten whorls; suture shallow. *Sculpture:* three beaded spirals of about equal size, the central row smaller on the apical whorls; beads well-developed, round, connected spirally by the keels; last whorl with a fourth beaded spiral. *Aper-*

ture: ovate; anterior canal closed, recurved; posterior canal semicircular; base with two smooth spiral cords. *Color:* apical and abapical rows of beads white or light-colored, remaining beaded spirals gray-brown maculated with lighter gray; protoconch brown; apical whorls white.

Shells are common in beach drift and at depths to 60 m. Shallow water shells seem to be more obese (length 8 mm, diameter 2 mm) and have more vibrant color than do the slender (length 10 mm, diameter 1.75 mm), pale-colored deep water shells from 60 m.

T. tuberculata was described from the Hawaiian Islands, but *T. confusa* (Kosuge, 1963a) from the Amami Islands appears to represent the species. The shells are similar in shape and sculpture to those of *T. granulata* Adams and Reeve, 1848, from the China Sea, but in that species the shells are uniformly gray-brown and the protoconch is unicarinate.

Triphora tubularis (Laseron, 1958a). Fig. 52 M. Length, 7 mm; diameter, 1 mm. *Shell:* elongate, flat-sided; last whorl with three beaded spirals; mauve. *Spire:* protoconch acuminate, of four cream-colored, unicarinate whorls; teleoconch of about twelve rather straight-sided whorls; suture indistinct, narrow. *Sculpture:* apical whorls with two, abapical whorls with three spirals of small beads about half their diameter apart, the central row smaller than the bordering rows; last whorl with an additional spiral and a smooth keel. *Aperture:* ovate; posterior notch absent; anterior canal short, recurved. *Color:* mauve.

Worn shells are fairly common in beach drift and living animals have been dredged at moderate depths.

T. tubularis was described from New South Wales, Australia, and has been reported from the Amami Islands (Kosuge, 1963a).

Additional Records

Neither *Triphora oryza* Pease, 1871a, nor *T. sulcosa* Pease, 1871a, described from the Hawaiian Islands, is identifiable from the description. Neither *T. collaris* Hinds, 1843, nor *T. hilaris* Hinds, 1843, reported from the "Sandwich Islands" by Melvill and Standen (1897), is known from Hawaii. Shells of *T. collaris* are of the same style as those of *Iniforis aemulans,* but the granules are more spirally elongate and the brown color is confined to the suture.

Superfamily EPITONACEA

The two families comprising the Epitonacea, the Epitoniidae and the Janthinidae, have in the past been grouped as the Ptenoglossa, a name derived from the type of radula characteristic of the group, a short broad ribbon with many similar, usually fanglike teeth. Epitonaceans are carnivorous, the benthic epitonids feeding on sea anemones and corals, the pelagic janthinids preying on siphonophores and other pelagic coelenterates.

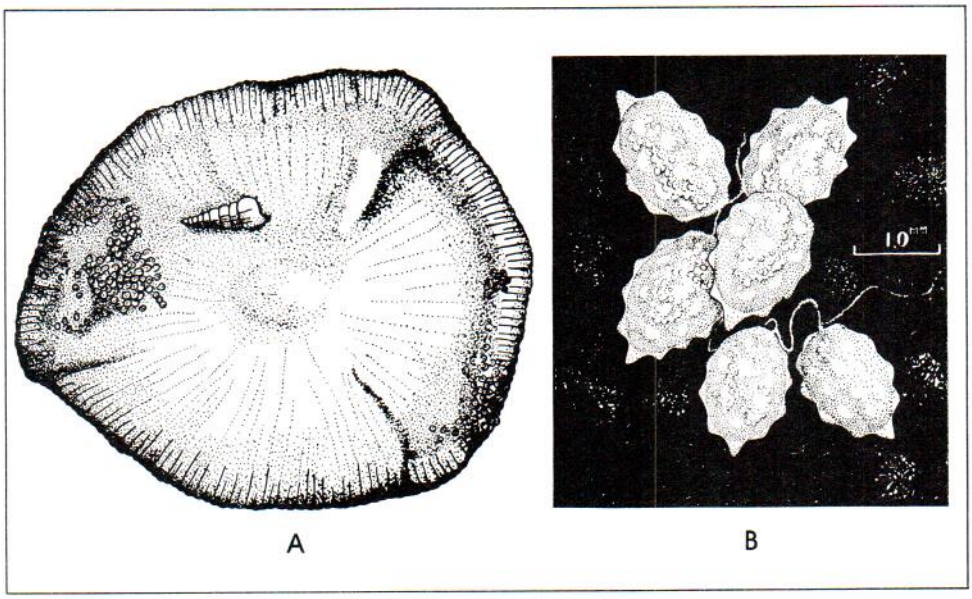


Figure 53.—A. *Epitonium ulu* with egg mass on the undersurface of *Fungia scutaria*. White area to the right of the snail is a lesion in the coral tissue (after Bosch, 1965). B. *E. ulu* egg capsule (by E. B. Guinther).

Family **Epitoniidae**

The shells of epitonids, of which *Epitonium scalare* Linnaeus, 1758, the precious wentletrap, is perhaps the best known, are distinguished by their numerous, prominent axial costae which ascend the spire, and by the entire, circular aperture. There is a tendency for some shells to uncoil (Fig. 54 F). The shells are usually white but some have a brown band or are entirely brown, the brown color apparently associated with the animal's diet. The operculum is horny, with a central nucleus and few whorls.

Epitonids are associated with anthozoan coelenterates, corals, or sea anemones. Some are permanent ectoparasites, others foraging predators (Robertson, 1963). In Hawaii four species feed on the sea anemone *Aiptasia*, at least in the laboratory, and another (*Epitonium fucatum*) feeds on *Radianthus papillosa*. One species, *Epitonium ulu*, is associated with the solitary coral, *Fungia scutaria* (Fig. 53).

Epitonids are protandrous hermaphrodites. There is no penis in the male phase; spermatozeugmata are formed in the testis and bear eupyrene sperm to the females. The eggs are small, deposited in triangular egg capsules (Fig. 53b). The planktonic veligers are bilobed, with one lobe larger than the other (J. B. Taylor, 1975). The protoconch is shaped like a tear drop. A conspicuous feature in the veligers is the purple-black hypobranchial gland which releases brilliant purple secretions. Robertson (1963) notes the dye in the adults may be toxic. Metamorphosis occurs when three to six whorls are complete (J. B. Taylor, 1975).

Epitonids show several adaptations associated with their predatory habits, among them tendencies to exhibit high population densities, early maturity, and rapid growth. More than 200 specimens of *Epitonium perplexum* were found in an hour in Hilo Bay

in the spring of 1914 (Thaanum, MS), and other population "blooms" have been noted (Harrison, pers. comm.). *E. ulu* may complete its entire life cycle in 39 days: five days in intracapsular egg development, 14 days in the plankton, and 20 days from settlement to the production of the first egg mass (Guinther, 1970; J. B. Taylor, 1975).

Cirsotrema varicosa (Lamarck, 1822). Fig. 54 D. Length, 28 mm; diameter, 11 mm. *Shell:* elongate-conic; solid; with a basal disk; not umbilicate; costae crenulate, the interspaces crossed by spiral grooves; white. *Spire:* six to eight convex whorls; suture constricted. *Sculpture:* obliquely set, imbricate axial costae, the interspaces crossed by spiral grooves. *Aperture:* circular; peristome striate. *Color:* white; operculum dark red-brown.

These epitonids are rare, found at depths of 3 to 160 m.

C. varicosa is a well-known species in the Indo-West Pacific and has been reported from Kii Peninsula, Japan (Habe, 1964).

Epitonium alatum (Sowerby, 1844). Fig. 54 C. (Synonym: *Epitonium arestum* Tinker, 1952.) Length, 17 mm; diameter, 8 mm. *Shell:* conical, obese; without a basal disk; narrowly umbilicate; costae angled and hooked; intercostal spaces smooth; white. *Spire:* protoconch of two or more conical whorls; teleoconch of six convex whorls, the abapical whorls enlarged; suture strongly constricted. *Sculpture:* strong, well-separated, platelike costae angled and hooked at the shoulders of the whorls; intercostal spaces smooth. *Aperture:* circular, outer lip with a hook near the suture; operculum dark brown. *Color:* white, occasionally with broadly diffuse brown bands.

Shells are common in beach drift, and have been dredged at depths of 160 and 200 m.

E. alatum was described from the Philippines and has been recorded from Singapore and Fiji.

Epitonium fucatum (Pease, 1861a). Fig. 54 I. (Synonym: *Epitonium furcatum* [*sic*] Edmondson, 1933.) Length, 14 mm; diameter, 6 mm. *Shell:* elongate-conic, solid; without a basal disk; not umbilicate; axial costae sharp and hooked; interspaces cancellate; white. *Spire:* eight or nine convex whorls plus the protoconch; suture strongly constricted. *Sculpture:* seven or eight distant, compressed costae with prominent hooks at the suture; interspaces microscopically cancellated by axial and spiral striae. *Aperture:* oval; outer lip bordered by a varix with a hook at the suture; columella thickened and strongly curved. *Color:* white, often with a faint brown band encircling the center of each whorl.

This epitonid has been found in shallow water in Kaneohe Bay, Oahu, and Kealakekua Bay, Hawaii. In Kaneohe Bay it is associated with the large sea anemone *Radianthus papillosa* on which it feeds (Guinther, 1970 as *Marcanthea cookei).*

This species was described from the Hawaiian Islands. Cernohorsky (1972a) records it as "uncommon throughout the tropical Pacific." Shells of *E. fucatum* are distinguished from those of *E. alatum* by their slender form and the cancellate sculpture between the costae.

Epitonium hyalinum mokuolensis Pilsbry, 1921. Fig. 54 G. Length, 8 mm; diameter, 5 mm. *Shell:* loosely coiled; without a basal disk; deeply umbilicate; thin

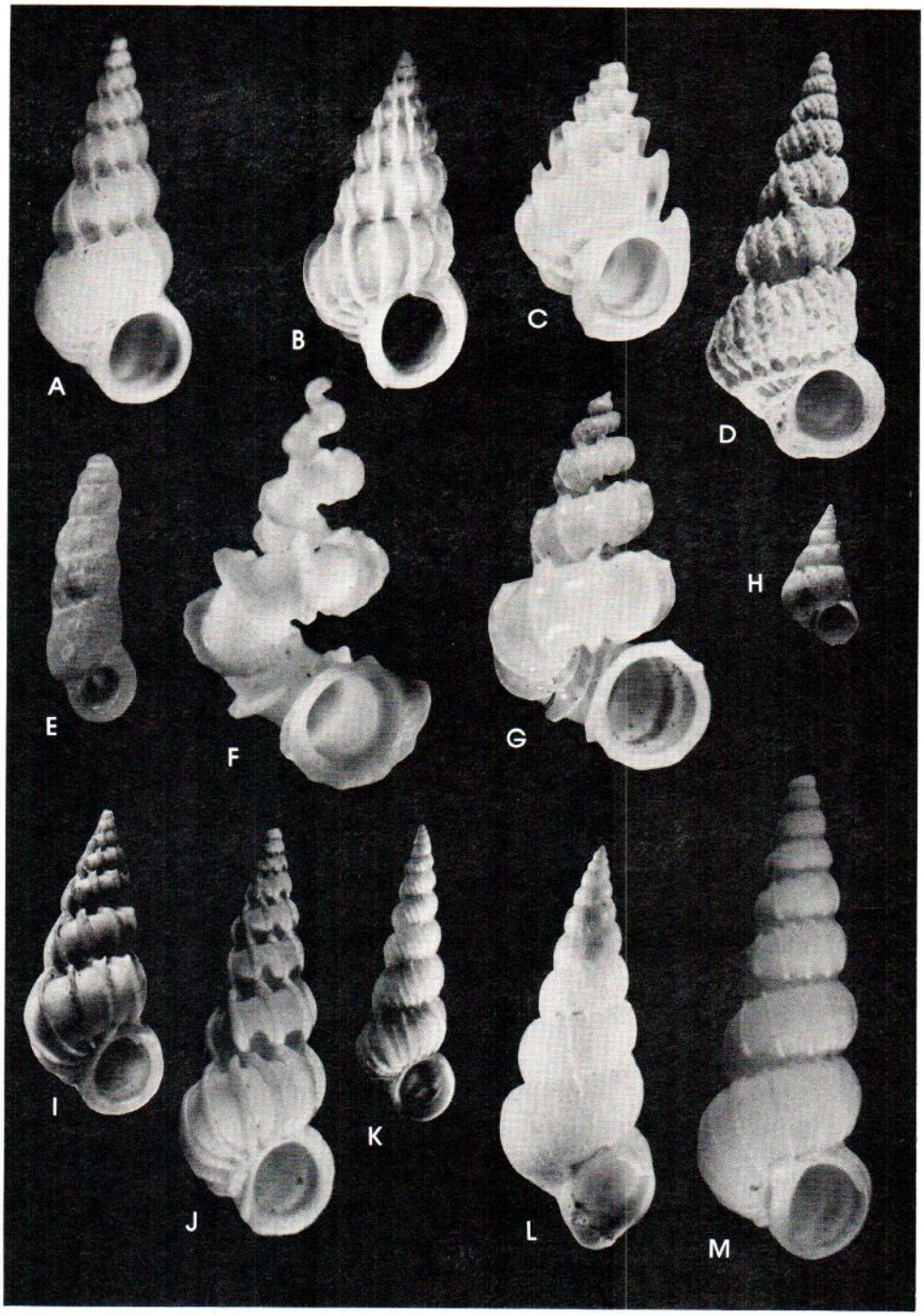


Figure 54.—**Epitoniidae.** A. *Epitonium paumotensis*, length 9 mm. B. *E. perplexum*, length 20 mm. C. *E. alatum*, length 17 mm. D. *Cirsotrema varicosa*, length 28 mm. E. *Opalia attenuata*, length 10 mm. F. *E. revolutum*, length 3 mm. G. *E. hyalinum mokuolensis*, length 8 mm. H. *Epitonium millecostatum*, length 10 mm. I. *Epitonium fucatum*, length 14 mm. J. *E. kanemoe*, length 13 mm. K. *E. umbilicatum*, length 10 mm. L. *E. ulu*, length 14 mm. M. *E. oahuense*, length 15 mm.

and hyaline. *Spire:* protoconch of two minute whorls; teleoconch of five convex whorls almost separate from one another, rapidly enlarging from the acute apex. *Sculpture:* sharp, well-defined obliquely ascending axial costae; interspaces smooth. *Aperture:* circular; outer lip reflected. *Color:* transparent, glassy, white.

These mollusks have been found with the swimming sea anemone *Boloceroides lilae* in Kaneohe Bay, Oahu, but are apparently rare (Guinther, 1970).

The species is distributed throughout the Indo-West Pacific.

The Hawaiian shells are considered subspecifically distinct because of their small size.

Epitonium kanemoe Pilsbry, 1921. Fig. 54 J. (Synonym: *Scalaria decussata* Pease, 1868b, non Lamarck, 1804 or Wood or Philippi.) Length, 13 mm; diameter, 2 mm. *Shell:* small, elongate-conic; with frilled costae; intercostal spaces spirally striate; white. *Spire:* protoconch of four, smooth, white whorls; teleoconch of eight convex whorls; suture constricted. *Sculpture:* 16 costae, about half encircling the spire but not continuous and with broad points or hoods at the suture; spiral sculpture of numerous close-set, equal threads between the varices. *Aperture:* rounded; peristome complete. *Color:* white.

These epitonids are common as veligers in the plankton in Kaneohe Bay, Oahu, and juveniles feed on the sea anemone *Aiptasia* in the laboratory (J. B. Taylor, 1975). Shells are occasionally found in beach drift.

E. kanemoe was described from the Hawaiian Islands.

Epitonium millecostatum (Pease, 1861a). Fig. 54 H. Length, 6.5 mm; diameter, 3.5 mm. *Shell:* short, thin; without a basal disk; umbilicate; with numerous fine costae equal in diameter to the interspaces; white. *Spire:* protoconch of four shining, white, obliquely tilted whorls; teleoconch of six adjacent, convex whorls; suture deeply constricted. *Sculpture:* numerous fine, oblique costae, the interspaces equal in diameter and spirally striated. *Aperture:* circular, the parietal region covered by a moderately thick callus which is not continuous. *Color:* white.

Living animals are uncommonly found on reef flats and shells have been found embedded in the "soft coral," *Zoanthus*.

E. millecostatum was described from the Hawaiian Islands; it has also been recorded from Natal, South Africa (Smith, 1901).

Epitonium oahuense Pilsbry, 1921. Fig. 54 M. Length, 15 mm; diameter, 5 mm. *Shell:* elongate-conic, slender; thin; without a basal disk; umbilicate; axial costae thin; interspaces smooth; shining white, sometimes clouded with brown. *Spire:* protoconch of three smooth, white whorls; teleoconch slender, high-spired; of six and one-half convex whorls; suture constricted. *Sculpture:* thin, small axial costae continuous from whorl to whorl and ascending the spire obliquely; interspaces smooth. *Aperture:* ovate; peristome smooth. *Color:* glassy white, sometimes clouded with brown.

Shells are occasionally found in beach drift and living animals have been dredged from depths of more than 50 m.

E. oahuense was described from the Hawaiian Islands. The shells are distinguished from those of *E. ulu* by the more convex whorls, slender form, and slightly more prominent costae.

Epitonium paumotensis (Pease, 1868b). Fig. 54 A. Length, 9 mm; diameter, 5 mm. *Shell:* elongate-oval, solid; without a basal disk; not umbilicate; costae linear; intercostal spaces smooth; white. *Spire:* teleoconch of six convex whorls; suture constricted. *Sculpture:* narrow, smooth costae which are continuous from whorl to whorl; interspaces between the costae smooth. *Aperture:* circular, peristome heavy and reflected. *Color:* white.

Shells are abundant in beach drift but nothing is known of the habits of the living animals.

E. paumotensis was described from the Tuamotus.

Epitonium perplexum (Deshayes, 1863). Fig. 54 B. (Synonyms: *Scalaria perplexa* Pease, 1868b; *Epitonium lamellosa* Bryan, 1915; *E. pyramis* Tinker, 1952.) Length, 20 mm; diameter, 8 mm. *Shell:* elongate-conic, thin; with a basal disk; not umbilicate; axial costae sharp and hooked; white, sometimes banded with brown. *Spire:* protoconch of three and one-half conical whorls; teleoconch of nine to twelve rapidly enlarging, convex whorls; suture deeply impressed. *Sculpture:* nine to ten compressed, sharp, hooked, axially striate costae ascending the spire obliquely and impressed at the suture (costae smooth in beachworn shells); interspaces between the costae smooth. *Aperture:* abbreviately oval, outer lip reflected. *Color:* white, often with a dark brown band below the suture, occasionally entirely brown.

These epitonids are common in shallow water in tide pools, and on reefs; shells are common in beach drift. Thaanum (MS) noted that specimens were extremely abundant during the last week in February and the first week in March, 1914.

E. perplexum was described from Réunion; it has also been reported from New South Wales (Kerslake, 1968), southern Japan, and the Marshall Islands (Ladd, 1972).

Epitonium revolutum (Hedley, 1899). Fig. 54 F. Length, 3 mm; diameter, 1.5 mm. *Shell:* minute, uncoiled; with prominent, keel-like costae, interspaces smooth; white. *Spire:* protoconch of four small, conical whorls; teleoconch disjunct, of three and one-half cylindrical whorls. *Sculpture:* eight slightly elevated costae on the last whorl, the costae hooked at the shoulder; shell smooth and glossy between the costae. *Aperture:* circular; peristome reflected. *Color:* white.

These epitonids apparently occur in deep water around the windward islands at depths of 100 to 150 m, but have been found in beach drift on Midway.

E. revolutum was described from a single specimen found on the lagoon beach at Funafuti, Ellice Islands, and has since been recorded from Miocene marls in Palau (Ladd, 1972).

Epitonium ulu Pilsbry, 1921. Figs. 53; 54 L. Length, 14 mm; diameter, 5 mm. *Shell:* elongate-conic, thin; without a basal disk; umbilicate; with obsolete costae; white. *Spire:* protoconch of five smooth, white whorls; teleoconch of up to ten convex whorls; suture deeply constricted. *Sculpture:* fine axial costae almost vertically ascending the spire, the costae obsolete on the apical whorls. *Aperture:* ovate; no peristome; columellar lip reflected below. *Color:* white.

This epitonid is the most common species in the genus in Kaneohe Bay, Oahu, where it is associated with the solitary coral *Fungia scutaria* Lamarck (Guinther, 1970). The animals apparently live at the base of the coral, creeping about through the

lamellae and depositing their eggs in the area where they feed. In experimental tanks each coral became infected with one to six snails over a three-week period (Bosch, 1965). Field growth experiments in Kaneohe Bay indicate that sexual maturity is reached in perhaps little more than two weeks after the larva has settled out of the plankton (Guinther, 1970).

E. ulu was described from the Hawaiian Islands. The costae are less developed than in other Hawaiian epitonids. A similar species, *E. costulatum* (Kiener), is also associated with *Fungia* sp. in the southwestern Philippines (Robertson, 1963, 1970a).

Epitonium umbilicatum (Pease, 1869b). Fig. 54 K. Length, 10 mm; diameter, 3 mm. *Shell:* elongate, turreted; umbilicate; with narrow costae and fine spiral striae; white. *Spire:* protoconch of five conical whorls; teleoconch of ten convex whorls; suture constricted. *Sculpture:* 11 costae about half encircling the spire but not continuous from whorl to whorl; spiral sculpture of fine, remote, impressed striae. *Aperture:* circular; peristome complete. *Color:* white.

Shells are occasionally found in beach drift, and veliger larvae were identified in the plankton at Kaneohe Bay, Oahu, in September (J. B. Taylor, 1975).

E. umbilicatum was described from the Hawaiian Islands.

Opalia (Nodiscala) attenuata (Pease, 1861a). Fig. 54 E. Length, 11 mm; diameter, 3.5 mm. *Shell:* elongate, compressed, solid; without a basal disk; not umbilicate; axial sculpture of low ribs; white. *Spire:* protoconch paucispiral, of one and one-half white whorls; teleoconch of rather flattened whorls; suture shallow, crenulated. *Sculpture:* low, rounded axial ribs not continuous the length of the whorls and with faint spiral threads; a single varix across the fifth whorl. *Aperture:* subcircular; peristome complete and thickened, slightly reflected at the edge. *Color:* white.

Shells are fairly common in beach drift, but nothing is known of the habits of the living animals.

This species was described from the Hawaiian Islands, and has also been reported from Kii Peninsula, Japan, at depths of 5 to 20 m (Habe, 1964), and the Cocos-Keeling Islands (Maes, 1967).

Family **Janthinidae**

These gastropods are pelagic, floating on the surface of the sea with the aperture of their fragile, lavender shells held upward (Fig. 6 F). They are usually associated with the coelenterates *Velella* and *Physalia*, the Portuguese-man-of-war, on which they feed, and with which they are cast up on shorelines after a storm at sea.

The shells of the Janthinidae are among the thinnest of gastropod shells. They are globose, with a low spire, the last whorl is inflated, and there is a large aperture but no operculum. The shells are of varying shades of blue to violet.

The sexes are separate. *J. janthina* is viviparous, producing living young. In *J. globosa* and *J. exigua* the egg capsules are attached to the float. The veliger larvae are bilobed, and, as in the epitonids, larval janthinids have a hypobranchial gland which produces violet secretions (J. B. Taylor, 1975). The protoconchs are ovate.

The three species recorded here are found throughout the Pacific, Indian, and Atlantic oceans.

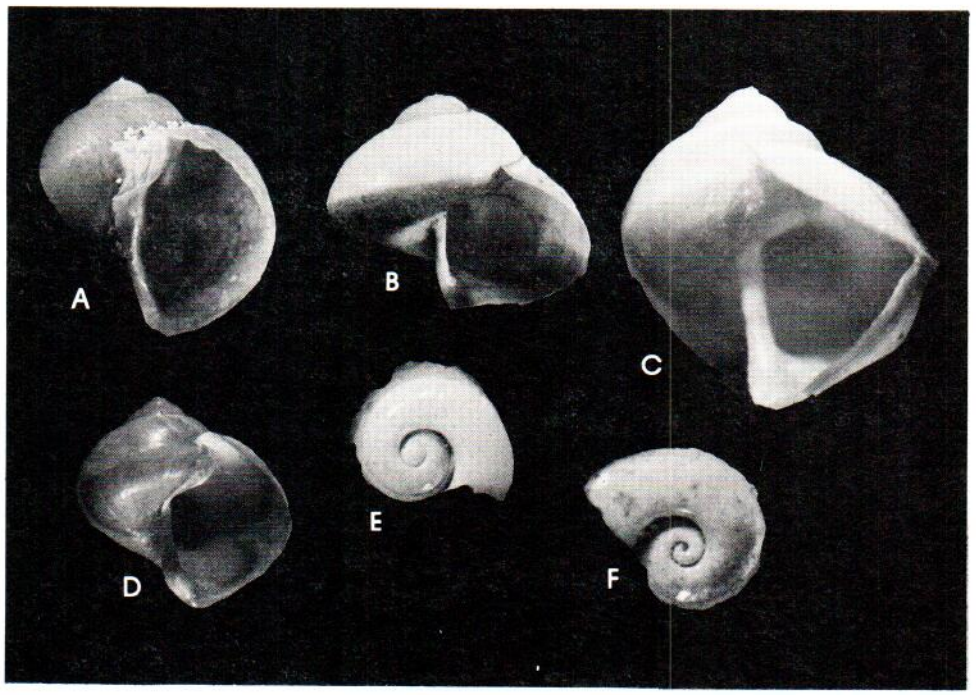


Figure 55.—**Janthinidae** and **Atlantidae.** A, D. *Janthina globosa*, height 18 mm. B. *J. janthina*, height 26 mm. C. *J. exigua*, height 12 mm. E, F. *Atlanta* sp., diameter 3 mm.

Janthina exigua Lamarck, 1816. Fig. 55 C. (Synonym: *Janthina bifida* Nuttall, Jay, 1839.) Height, 12 mm; diameter, 12 mm. *Shell:* globose; outer lip with a prominent notch; light violet. *Spire:* apex rather tall, whorls slightly flattened from above; suture distinct. *Sculpture:* regular, oblique, deep furrows slanting from the suture to the middle of the whorl, where they form a sinus. *Aperture:* outer lip distinctly notched. *Color:* light violet.

Shells in Hawaiian collections have been recorded only from the leeward islands.

Janthina globosa Swainson, 1822. Fig. 55 A, D. (Synonym: *Janthina prolongata* Blainville, Laursen, 1953.) Height, 18 mm; diameter, 18 mm. *Shell:* globose; spire short; aperture large; dark violet. *Spire:* whorls and apex somewhat depressed; suture distinct. *Sculpture:* fine striae curving over a low spiral keel on the last whorl. *Aperture:* relatively large for the size of the shell; columella twisted. *Color:* dark violet.

Janthina janthina (Linnaeus, 1758). Fig. 55 B. (Synonym: *Janthina fragilis* Lamarck, Edmondson, 1933.) Height, 26 mm; diameter, 26 mm. *Shell:* trochoid, flattened, whorls slightly angular; light purple-white above, dark violet below. *Spire:* three and one-half whorls; periphery of whorls often angled. *Aperture:* outer lip slightly sinuate. *Sculpture:* with microscopic, oblique striations which are especially prominent on the base. *Color:* upper surface lavender to white, base dark violet.

Superfamily EULIMACEA

Family **Eulimidae**

Eulimids are recognized by their smooth, polished, white, high-spired or globose shells, and by their association with echinoderms. Unfortunately, there is no agreement as to the number of families to which these mollusks should be assigned, or the generic names which should be applied. Keen (1971) recognizes a single family, the Eulimidae; Abbott (1974) distinguishes the Melanellidae (= Eulimidae) with high spired, nonumbilicate shells, the Stiliferidae with globose shells parasitic on starfish and sea urchins, and the Aclididae with high-spired umbilicate shells; Ivanov (1952) and Gooding and Lützen (1973) suggest that more than two families should be recognized. There is also argument as to whether *Balcis, Melanella,* or *Eulima* should be used for the high-spired white shells associated with holothurians and whether the small, fragile, dorso-ventrally compressed shells should be referred to as *Subularia, Leiostraca, Eulima* or *Strombiformis* (see Dell, 1956; Keen, 1971; Abbott, 1974). In this discussion I distinguish five genera in one family (adapted from Keen, 1971):

1. Apex mucronate or stiliform, with a minutely pointed tip 2
   Apex evenly tapered 3

2. Shell globose in outline ..... *Echineulima*
   Shell conic in outline ..... *Mucronalia*

3. Periphery of whorls rounded, not keeled 4
   Periphery of whorls with a keel ..... *Scalenostoma*

4. Slender, dorsoventrally compressed, aperture elongate ..... *Eulima*
   Conical, usually broad, aperture short ..... *Balcis*

Eulimids exhibit varying degrees of mutualism with echinoderms: some are apparently migratory, crawling freely over the surface of holothurians or among the spines of echinoids; some are attached to the host by a short proboscis; others are embedded in the epidermis of a sea cucumber or starfish, or live in the coelom. The anatomy is modified in association with their mode of life. Most apparently lack a radula and jaws, feeding by means of the pharynx which is modified as a buccal pump. Some are hermaphroditic, either protandrous or consecutive; others are dioecious. In Hawaii pelagic veliger larvae associated with 11 species have been found in the plankton; the protoconch is shaped like a teardrop and the velum is bilobed (J. B. Taylor, 1975).

Both shells and soft parts reflect the habits of the animals: those which are free-living *(Balcis kanaka)* have rather transparent shells and brightly colored animals; those which are attached to sea cucumbers *(B. aciculata* and *Mucronalia nitidula)* have solid, porcelaneous shells and the animals are white or decorated with yellow on the tentacles and foot. The endoparasites *(Stilifer linckiae)* that live in the body wall of starfish have thin, fragile shells which are covered by a large pseudopallium.

Most shallow water species of *Balcis* and *Mucronalia* in Hawaii are associated with holothurians. Along some areas of the shores of Oahu and Kauai at least 60 per

cent of the most commonly occurring sea cucumber, the black, sand-covered *Holothuria atra,* are host to the gastropods; lesser numbers of *Actinopyga mauritiana* (40 per cent) and *Holothuria cinerascens* (30 per cent) are affected. Only occasional specimens of *Holothuria fuscorubra* and *Actinopyga parvula* have been found with eulimids. Most holothurians are host to several eulimid species and one species of eulimid may be found on different species of holothurians.

The occurrence of *Echineulima* on echinoids appears to be more sporadic than that of *Balcis* and *Mucronalia* on holothurians. *Echineulima thaanumi* was recorded on *Diadema* in Hilo Bay in 1918 but not recorded there again until 1948 (Bromley, 1963). Of more than 200 specimens of *Heterocentrotus mamillatus* examined in Kealakekua Bay, Hawaii, in October, 1968, only one was parasitized. On the other hand, six percent of the intertidal shingle urchin, *Colobocentrotus atratus,* at Keaau, Hawaii, were host to from one to four specimens of *Echineulima robusta* between January and August, 1975.

Balcis acanthyllis (Watson, 1886). Fig. 56 A. Length, 1.5 mm; diameter, 0.5 mm. *Shell:* slender, attenuate; suture flush; transparent. *Spire:* very slightly curved; apex acute; whorls flat-sided; suture barely impressed, oblique. *Sculpture:* growth striae only. *Aperture:* ovate, slightly truncated anteriorly. *Color:* transparent glassy white, occasionally with minute brown spots on the penultimate whorl and tinted with red-brown around the outer lip.

Shells of these eulimids are found in sediments at depths of 25 to 50 m.

B. acanthyllis was described from the Hawaiian Islands.

Balcis aciculata (Pease, 1861b). Fig. 56 B. (Synonym: *Balcis kahoolawensis* Pilsbry, 1917.) Length, 9 mm; diameter, 3 mm. *Shell:* subulate; solid and porcelaneous; suture flush; varices irregular; milky white. *Spire:* straight, the apex acute, slightly flexed; whorls straight-sided; last whorl ovate; suture flush, subsutural band occasionally visible. *Varices:* irregular. *Aperture:* small, oval; outer lip falling straight from suture, slightly thickened. *Color:* milky white. *Animal:* foot white, margined with yellow; tentacles yellow splashed with red at the base.

B. aciculata is the most abundant of the shallow-water eulimids. The animals occur loosely attached to the dorsal, ventral, and lateral surfaces of at least four species of holothurians, *Holothuria atra, H. cinerascens, Actinopyga parvula,* and *A. mauritiana.* As many as 15 gastropods have been found on a single sea cucumber.

This species was described from the Hawaiian Islands and is widely distributed in the Indo-West Pacific: shells from Mauritius and Tahiti are indistinguishable from those collected in the Hawaiian Islands. Shells of *B. aciculata* differ from those of *B. acicula* (Gould, 1849) from Fiji in their slightly bulging and flexed apical whorls.

Balcis brunnimaculata Kay, new species. Fig. 56 F, G. Length, 3 mm; diameter, 1 mm. *Shell:* conic; last whorl angled; white with minute brown spots. *Spire:* protoconch of a single blunt, dome-shaped whorl; teleoconch of eight straight-sided whorls, the last slightly angled; suture flush with the whorls, weakly defined. *Varices:* irregular, deep, extending the length of the whorls. *Aperture:* ovate; outer lip slightly thickened, convex at the base; columella curved. *Color:* white with two or three

minute brown spots on most of the whorls; occasionally with a shadowy subsutural band occupying about one-third of each whorl.

These gastropods are found on the undersurfaces of rocks in shallow water shoreward on fringing reefs and in tide pools; occasional specimens have been seen on the sea cucumber *Actinopyga mauritiana*.

Type locality: a tide pool at Poipu Beach, Kauai. *Holotype:* Bernice P. Bishop Museum No. 9780. Paratypes: Australian Museum; British Museum (Natural History); U.S. National Museum.

These small eulimids are distinguished from others with brown spots, such as *Eulima piperita* Hedley, 1909, from Queensland, Australia, and *Lentigobalcis punctozonata* Habe, 1961c, from Japan, by their compact shells with the slightly angular last whorl. Derivation of name: *brun,* Anglo-Saxon — brown; *macula,* Latin — spot. Refers to the brown spots on the shells.

Balcis bryani (Pilsbry, 1917). Fig. 56 I. Length, 9 mm; diameter, 4 mm. *Shell:* elongate-conical; spire flexed; thick and solid; suture impressed, whorls convex; shining white. *Spire:* apical whorls strongly flexed to the right; suture deeply impressed. *Varices:* linear, receding dorsally on the apical whorls. *Aperture:* subcircular; columella arched; outer lip almost straight in profile. *Color:* shining white. *Animal:* white margined with bright yellow-green; foot bilobed.

These animals have been found both free in tide pools and on the surface of the holothurian *Actinopyga parvula*.

B. bryani was described from the Hawaiian Islands.

Balcis conoidalis (Sowerby, 1865). Fig. 56 E. Length, 14 mm; diameter, 5 mm. *Shell:* elongate-conical, last whorl angulated; spire straight; sutures impressed; varices irregular; porcelaneous white. *Spire:* straight; nine or ten slightly convex whorls; last whorl angled at the periphery; spire four times the height of the aperture; suture impressed. *Varices:* irregularly distributed, one on each whorl. *Aperture:* ovate, outer lip angled. *Color:* porcelaneous white.

Shells are common in beach drift but nothing is known of the habits of the living animals.

B. conoidalis was described from the Hawaiian Islands.

Balcis cumingii (A. Adams, 1854a). Fig. 56 L. (Synonym: *Melanella cumingi medipacifica* Pilsbry, 1917.) Length, 24 mm; diameter, 7.5 mm. *Shell:* elongate-conical, last whorl convex; spire straight; suture impressed; varices irregular; porcelaneous white. *Spire:* straight; 10 to 11 slightly convex whorls; last whorl somewhat angled in small specimens, ovate in larger shells; spire four times the length of the aperture; suture impressed, often with a narrow subsutural band. *Varices:* irregularly distributed, usually one on each whorl. *Aperture:* ovate, outer lip almost straight, not retracted at the base. *Color:* porcelaneous white. *Animal:* foot white, margined with golden yellow; tentacles yellow.

This is the largest and most conspicuous eulimid in Hawaiian waters, and commonly occurs on *Actinopyga parvula;* two or three gastropods are often found on a single holothurian.

B. cumingii was described from Lord Hood Island; it appears to be widespread in the Indo-West Pacific and has been recorded from Clipperton Island (Hertlein and Allison, 1966).

Balcis inflexa (Pease, 1868b). Fig. 56 H. (Synonym: *Melanella vafra* Pilsbry, 1917.) Length, 6 mm; diameter, 2.5 mm. *Shell:* elongate-conical; last whorl angular; suture impressed; varices irregular; white. *Spire:* straight or barely flexed; whorls only slightly convex; suture impressed. *Varices:* irregular, linear abaperturally but scattered elsewhere. *Aperture:* ovate; outer lip projecting and thin. *Color:* porcelaneous white.

This species occurs on at least three species of holothurian, including *Actinopyga mauritiana*, and *Holothuria atra*. Specimens are common but not abundant, with three to five gastropods found loosely attached to a single sea cucumber.

B. inflexa was described from the Tuamotus and has also been recorded from Clipperton Island (as *B. vafra* Pilsbry, Hertlein and Allison, 1966).

Balcis kanaka (Pilsbry, 1917). Fig. 56 C. Length, 4 mm; diameter, 1.5 mm. *Shell:* subulate; spire flexed; suture flush; transparent. *Spire:* flexed to the right, the apex flexed in another direction; suture flush, with a wide, shadowy subsutural band on each whorl. *Varices:* linear, deep. *Aperture:* subovate, small; outer lip arching forward in profile. *Color:* transparent white. *Animal:* apical portions of the body pink, becoming gray-brown abapically with some dark red on the head; tentacles spotted with opaque white.

B. kanaka appears to be a free-living form and is common in crevices and depressions on the undersurfaces of rocks in shallow waters shoreward of fringing reefs.

This species was described from the Hawaiian Islands.

Balcis letsonae (Pilsbry, 1917). Fig. 56 D. Length, 4.5 mm; diameter, 2 mm. *Shell:* subulate, solid; spire slightly flexed; suture flush; porcelaneous white. *Spire:* attenuate, slightly flexed to the right; suture barely impressed; last whorl angled. *Varices:* linear, on the right, becoming dorsal apically. *Aperture:* small, ovate; outer lip curving forward strongly in the middle. *Color:* opaque white.

Beachworn shells are uncommon in drift and nothing is known of the habits of the living animals.

B. letsonae was described from the Hawaiian Islands.

Balcis solida (Sowerby, 1865). Fig. 56 K. Length, 7 mm; diameter, 2.5 mm. *Shell:* conical, attenuate; thick and solid; outer lip thick; white. *Spire:* apex attenuate; teleoconch of about five rather straight-sided whorls; suture barely impressed. *Aperture:* subcircular; outer lip greatly thickened. *Color:* white.

Shells are uncommon in beach drift.

B. solida was described from the Hawaiian Islands.

Balcis solidula (Adams and Reeve, 1848). Fig. 56 J. (Synonym: *Eulima opaca* Sowerby, 1865.) Length, 12 mm; diameter, 4 mm. *Shell:* subulate, solid; suture impressed, whorls convex; outer lip thick, projecting; porcelaneous white. *Spire:*

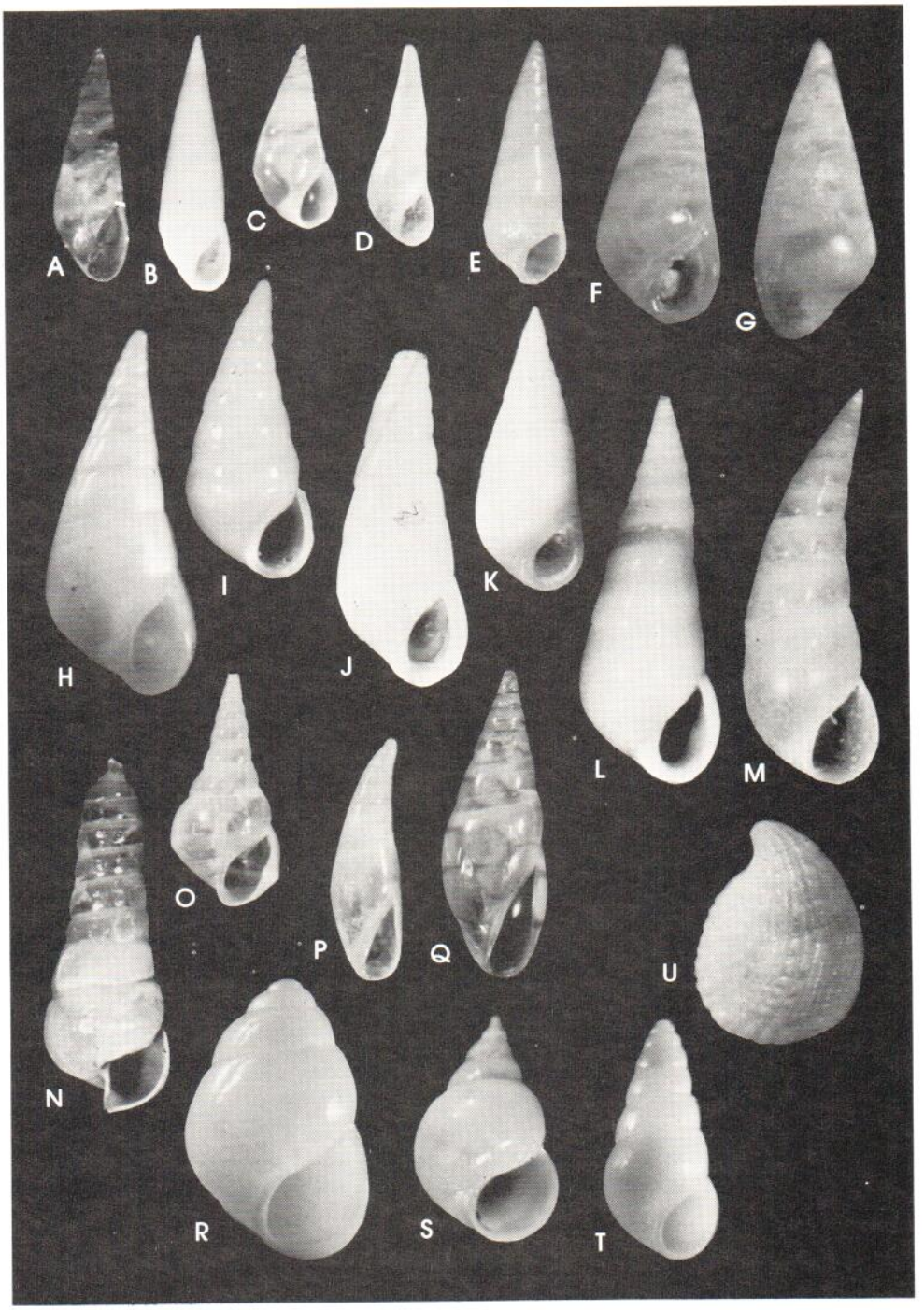


Figure 56.—**Eulimidae.** A. *Balcis acanthyllis*, length 1.5 mm. B. *B. aciculata*, length 9 mm. C. *B. kanaka*, length 4 mm. D. *B. letsonae*, length 4.5 mm. E. *B. conoidalis*, length 15 mm. F, G. *B. brunnimaculata*, length 3 mm (holotype). H. *B. inflexa*, length 8 mm. I. *B. bryani*, length 10 mm. J. *B. solidula*, length 12 mm. K. *B. solida*, length 7 mm. L. *B. cumingii*, length 24 mm. M. *B. thaanumi*, length 22 mm. N, O. *Scalenostoma carinata*, (N) length 12 mm; (O) length 8 mm. P. *Eulima metcalfei*, length 9 mm. Q. *E. peasei*, length 5 mm. R. *Echineulima mittrei*, length 8 mm. S. *E. robusta*, length 3 mm. T. *Mucronalia nitidula*, length 3 mm. U. *Thyca crystallina*, length 6 mm.

gently flexed to the right, often decollate; suture impressed; last whorl rounded. *Varices:* linear, ascending in a straight line from the suture on the last whorl. *Aperture:* ovate; outer lip straight, thick; columella arched. *Color:* porcelaneous or creamy white. *Animal:* foot white, tentacles dark golden yellow.

These gastropods occur on the sea cucumbers *Actinopyga mauritiana* and *Holothuria atra* and less frequently on other holothurians. Only one or two gastropods occur on a single holothurian.

B. solidula appears to be widely distributed in the Indo-West Pacific; shells from the Seychelles are comparable to the Hawaiian shells.

Balcis thaanumi (Pilsbry, 1917). Fig. 56 M. (Synonyms: *Eulima arcuata* Sowerby, 1865, non *E. arcuata* C. B. Adams, 1849; *Melanella lunata* Pilsbry, 1917; *M. ima* Pilsbry, 1917.) Length, 24 mm; diameter, 8 mm. *Shell:* elongate-conic; flexed; last whorl elongate; suture impressed; varices spiral; semitransparent. *Spire:* nine or more slightly convex whorls flexed to the right and back; last whorl elongate-convex; spire more than three times the length of the aperture; suture impressed. *Varices:* spiraling from the apertural suture dorsally. *Aperture:* ovate, outer lip arching forward, excavated in basal view; columella curved. *Color:* transparent white, polished.

B. thaanumi appears to be free-living; beachworn shells are occasionally found along the shores of northern beaches.

This species was described from the Hawaiian Islands (as *Eulima arcuata*, Sowerby, 1865), and is apparently widely distributed in the Indo-West Pacific, found in the Andaman Islands and the Torres Straits, and recorded from Clipperton Island (Hertlein and Allison, 1966).

Echineulima mittrei Petit, 1851a. Fig. 56 R. Length, 11 mm; diameter, 6 mm. *Shell:* ovate-conical; apex attenuate; glossy, white. *Spire:* apex conical, of three or four whorls which are disproportionately small compared with the inflated, convex whorls of the teleoconch; teleoconch of about five whorls; suture deeply impressed. *Aperture:* nearly circular; columella concave. *Color:* glossy, white.

These eulimids are ectoparasitic on the spiny black sea urchin, *Echinothrix diadema* (Pilsbry, 1921; Bromley, 1963).

E. mittrei was described without locality, but Pilsbry (1921) described Hawaiian shells as similar to those described by Petit. Pilsbry (1921) described another species of *Echineulima* found with *E. mittrei* on *Echinothrix*, *E. thaanumi*, distinguished by smaller shells (about 5 mm in length) with the last whorl globose and the outer lip flaring. Warén (pers. comm.) considers this species distinct from both *E. mittrei* and *E. robusta*.

Echineulima robusta Pease, 1860. Figs. 56 S; 57 A-C. (Synonym: *Echineulima eburnea* Deshayes, Lutzen and Nielsen, 1975.) Length, 2.5 mm; diameter, 1 mm. *Shell:* ovate-conic; apex attenuate; white. *Spire:* apex conical, slightly narrower than the whorls of the teleoconch; teleoconch of three or four slightly inflated whorls; suture impressed. *Aperture:* nearly circular; columella concave. *Color:* glossy, white.

These eulimids are parasitic on the shingle urchin, *Colobocentrotus atratus* and the slate pencil urchin, *Heterocentrotus mamillatus*. The mollusks are found on the

oral surface of the urchins. Parasitism is rare on *Heterocentrotus:* in October, 1968, only one of more than 200 specimens of *Heterocentrotus* at Kealakekua Bay was parasitized. About six percent of *Colobocentrotus* in the Hilo area, Hawaii, are parasitized, usually with two of the mollusks which are found on the oral surface near the edge of the disk (Fig. 57 C). The shells appear to be dimorphic, the larger shells presumably being those of females.

E. robusta was described from the Hawaiian Islands.

Eulima metcalfei (A. Adams, 1853b). Fig. 56 P. (Synonym: *?Subularia delicata* Pilsbry, 1917.) Length, 9 mm; diameter, 3 mm. *Shell:* subulate, spire flexed and dorsoventrally compressed; blue-white with axial streaks of chestnut brown. *Spire:* straight, just perceptibly flexed apically; suture barely impressed; whorls slightly convex; last whorl elongate with a flattened area between the columella and a short, angular ridge on the left side. *Varices:* linear on both the right and left sides. *Aperture:* very narrow; outer lip thin, arched; inner lip straight and heavily callused. *Color:* blue-white, transparent, with axial streaks of chestnut brown.

Specimens of *E. metcalfei* are common in beach drift; occasional living animals have been found on *Holothuria atra.*

This species is distributed throughout the Indo-West Pacific.

Eulima peasei Tryon, 1886. Fig. 56 Q. (Synonym: *Leiostraca distorta* Pease, 1861b, non Cantraine, 1835.) Length, 5 mm; diameter, 1.5 mm. *Shell:* subulate, dorsoventrally compressed; spire flexed; white. *Spire:* flexed in two directions; suture flush; whorls flattened; last whorl forming one-half the length of the shell, elongate, base rounded. *Varices:* inconspicuous, irregular. *Aperture:* elongate. *Color:* white with a wide, shadowy subsutural band.

Although shells are occasionally found in beach drift, living animals have not been found.

This species was described from the Hawaiian Islands.

Mucronalia nitidula Pease, 1861b. Fig. 56 T. (Synonym: *Mucronalia rosacea* Pease, 1861b.) Length, 4 mm; diameter, 2 mm. *Shell:* ovate; apex mucronate; suture impressed; whorls convex; polished, cream-white. *Spire:* apex of about four whorls which are disproportionately smaller than the abapical whorls and set somewhat obliquely; teleoconch of four to six convex whorls; suture impressed. *Aperture:* ovate; operculum thin, horn-colored. *Color:* opaque white, occasionally with a brown band. *Animal:* cream-colored with a splash of red on the tentacles anterior to the eyes.

M. nitidula is an ectoparasite of *Holothuria atra;* of 400 sea cucumbers examined, 50 percent were host to from one to five mollusks (Hoskin and Cheng, 1968). The mollusks feed by means of a long, contractile proboscis which is inserted into the body wall of the sea cucumber. When the proboscis is withdrawn, the snails can migrate freely over the body of the sea cucumber but are continuously attached to their host by a thin mucous thread which is secreted by gland cells on the crawling surface of the foot (Hoskin and Cheng, 1968). The sexes are separate; there is no penis in the male and spermatozoa may be transferred passively into the mantle cavity of the female by water currents (Hoskin and Cheng, 1968). Juvenile shells about 0.25 mm in

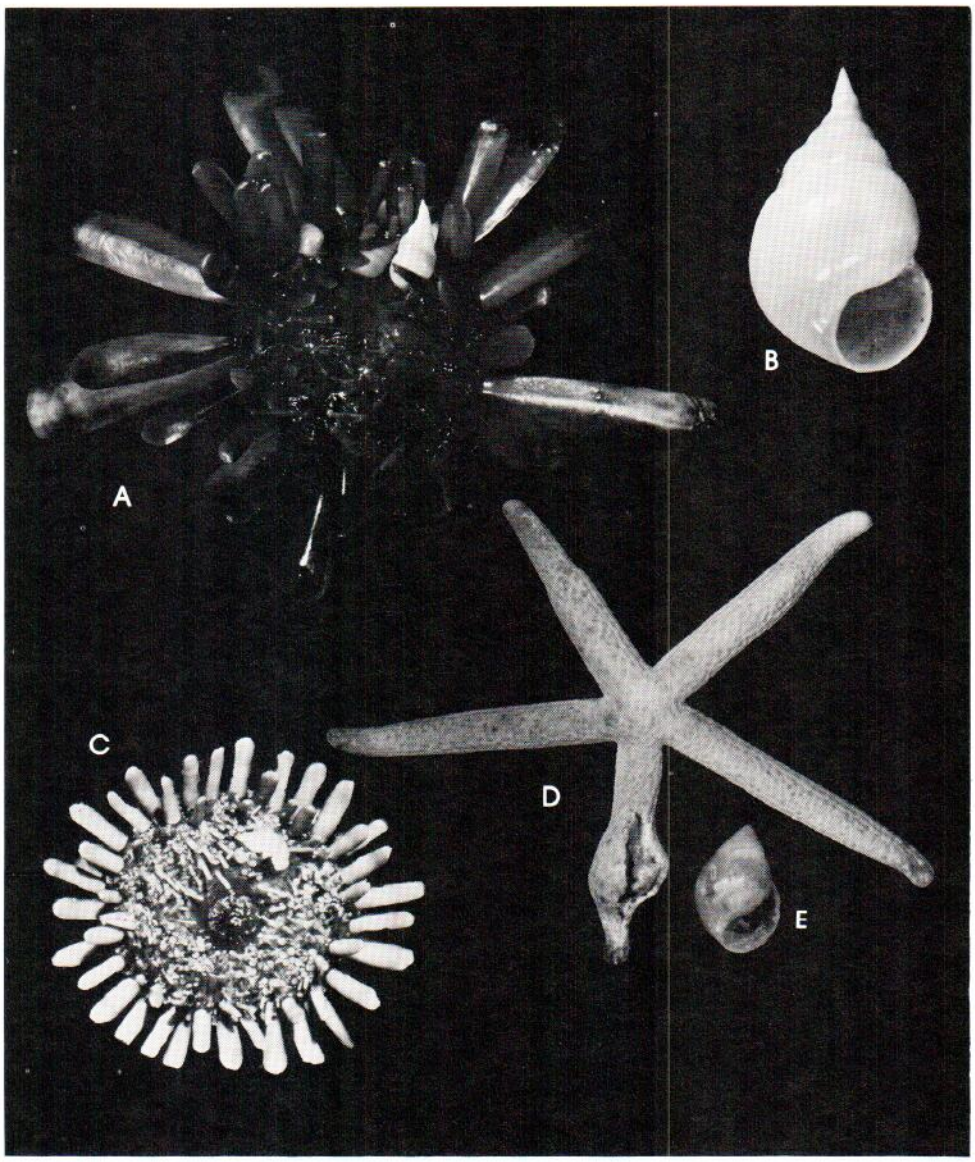


Figure 57.—A. *Echineulima robusta* on *Heterocentrotus mamillatus*. B. *E. robusta*, length 11 mm. C. *E. robusta* on *Colobocentrotus atratus*. D. *Stilifer linckiae* in the arm of *Linckia multifora*. E. *S. linckiae*, length 6 mm.

length can be found in small, sand-free pimples on the surface of the otherwise sand-coated holothurian.

M. nitidula was described from the Hawaiian Islands and is also found associated with *Holothuria atra* in Bali, the Philippines, Fiji, and Tahiti (Hoskin, 1968). The shells of *M. rosacea*, also described from the Hawaiian Islands, are indistinguishable except for their pink color.

Scalenostoma carinata Deshayes, 1863. Figs. 56 N, O. (Synonyms: *Scalenostoma apiculata* Souverbie, Pilsbry, 1917; *Stylifer deformis hawaiensis* Pilsbry, 1921; *S. deformis remotissimus* Pilsbry, 1921.) Length, to 13 mm; diameter, 4 mm. *Shell:* apical whorls slender, tapering, last whorl convex, inflated, keeled about the periphery; light, thin, transparent. *Spire:* slender, tapering, the apical whorls disproportionately slender compared to the convex, inflated last whorl; suture impressed. *Sculpture:* a spiral thread forming a keel about the periphery of the last whorl. *Aperture:* subcircular; outer lip thin. *Color:* transparent, glassy.

These mollusks live in the cavities of the coral *Porites*, and the shells are variable in shape. Small shells are common in beach drift.

S. carinata was described from Réunion. *Stylifer deformis hawaiensis* and *S. deformis remotissimus* were described from the Hawaiian Islands.

Stilifer linckiae Sarasin and Sarasin, 1887. Fig. 57 D, E. Length, 6 mm; diameter, 3 mm. *Shell:* ovate; whorls convex; thin, fragile, chalky white. *Spire:* five whorls plus the mucronate apex; whorls convex, abutting. *Sculpture:* microscopic growth striae only. *Aperture:* subcircular. *Color:* white. *Animal:* pseudopallium large, covering most of the shell.

S. linckiae is an endoparasite in the starfish *Linckia multifora*. The snails are found in enlarged areas or "galls," usually on the outer part or the lateral ventral side of the rays. The galls occupy a position within the body wall but are separated from the coelomic cavity by a layer of connective tissue, and open to the exterior by way of a small pore through which the egg masses are extruded (Davis, 1967; Tullis, 1968). One to five snails are found in a single gall (Davis, 1967), one usually much larger than the others. Each snail within a gall is independent and has its own aperture to the exterior (Lutzen, 1972). These gastropods appear to be consecutive hermaphrodites. Tullis (1968) reports testes and different developmental stages of sperm are present in small snails but only mature eggs occur in large snails. Lutzen (1972) suggests the young function as males, older individuals as females. The eggs are deposited on the substratum and veligers are released within four to eight days after deposition (Tullis, 1968). The tendency for spontaneous autotomy, the separation of one or more arms from the central disk, normally fairly high in starfish, is considerably reduced in parasitized rays, and this reduction may be associated with the parasite (Davis, 1967).

S. linckiae and its host were described from Ceylon.

Thyca crystallina (Gould, 1846). Fig. 56 U. Length, 10 mm. *Shell:* limpetlike, ovate, thin; with granular radiating ribs; apex posterior and lateral; white. *Protoconch:* glossy, conical, of two and one-half whorls, suture impressed and false-margined; resembling a miniature eulimid. *Sculpture:* granular, radiating ribs, the granules of irregular size and the interspaces of approximately equal diameter to the ribs. *Color:* white.

These animals are parasitic on the starfish *Linckia laevigata* Linnaeus and *L. multifora* Linnaeus. The shells of the female are conspicuous and sculptured, those of the males almost microscopic and smooth. The male lives on the right side of the foot of the female (Weaver, 1963a).

T. crystallina was described from Fiji. *Thyca* has been included in the Capulidae (see Thiele, 1931; Fretter and Graham, 1962) but is here transferred to the Eulimidae because of its distinctly eulimid protoconch and parasitic association with echinoderms.

Additional Records

Two species of *Mucronalia* described from the Hawaiian Islands have not been recognized since the original descriptions. The shells of *Mucronalia ovata* Pease 1861b and *M. sandvicensis* Sowerby, 1866, are indistinguishable, light and thin-shelled, with eight convex whorls, about 13 mm in length, 5 mm in diameter.

One species of the umbilicate genus *Niso* has also been described from Hawaii but has not been recorded in modern collections. The shell of *N. sandvicensis* Sowerby, 1866, is elongate-conic, solid, about 8 mm in length and 3 mm in diameter; the periphery of the last whorl is keeled and the shell is blue-white. *N. interrupta* Sowerby, 1865, was erroneously described from the islands. *Niso diomedae* "Dall," Mant, 1923, is a *nomen nudum*.

Ctenosculum hawaiense Heath, 1910 appears to be a barnacle, Ascothoracica (Warén, pers. comm.).

Two species of minute, semitransparent, glassy eulimids have been described from diademetid sea urchins in Hawaii (Ponder and Gooding, 1979). *Pulicicochlea (P.) calimaris*, 2.5 mm long, with an elongate spire, is found on the spines of *Echinothrix calamaris* from Indonesia to the Marquesas and Hawaii. *P. (Pseudoretusa) faba*, 2.7 mm long, with a cylindrical shell, is found on the spines of *Echinothrix diadema* from New Caledonia to Hawaii.

Superfamily STROMBACEA

Family **Strombidae**

The shells of strombids are recognized by the outer lip which is flared and spined in *Lambis* and *Tibia* and thick and undulated in *Strombus*. A feature of the outer lip is a U-shaped "stromboid" notch found toward the anterior end and through which one eye of the animal protrudes. In addition to the peculiar placement of the eyes and their extraordinary development, strombids are also characterized by some unique behavior patterns. Locomotion is by a leap rather than the more characteristic glide of other gastropods, the narrow muscular foot carrying an operculum which digs into the substrate. Leaps of more than a meter have been recorded when the behavior response is elicited in *Strombus maculatus* (Berg, 1972).

Strombids are herbivores, feeding on filamentous algae. The sexes are separate, and the egg masses are long gelatinous strings deposited on the substrate (Fig. 58 A, B). There is a pelagic veliger larva.

Although strombids are common to abundant throughout the tropical Pacific, only one species *(Strombus maculatus)* is found in shallow water in the Hawaiian Islands. Of the remaining six species recorded from the Islands, the endemic species *S. helli* is most common, and is a conspicuous component of dredge hauls at depths of more than 10 meters. Strombids were apparently at one time more abundant and diverse in Hawaiian waters than they are today: *Lambis chiragra chiragra*, *L. truncata*, and *Strombus mutabilis ostergaardi* (Fig. 59 D-F), an extinct endemic subspecies of the widely distributed *S. mutabilis*, are all found in Pleistocene fossil deposits on Oahu

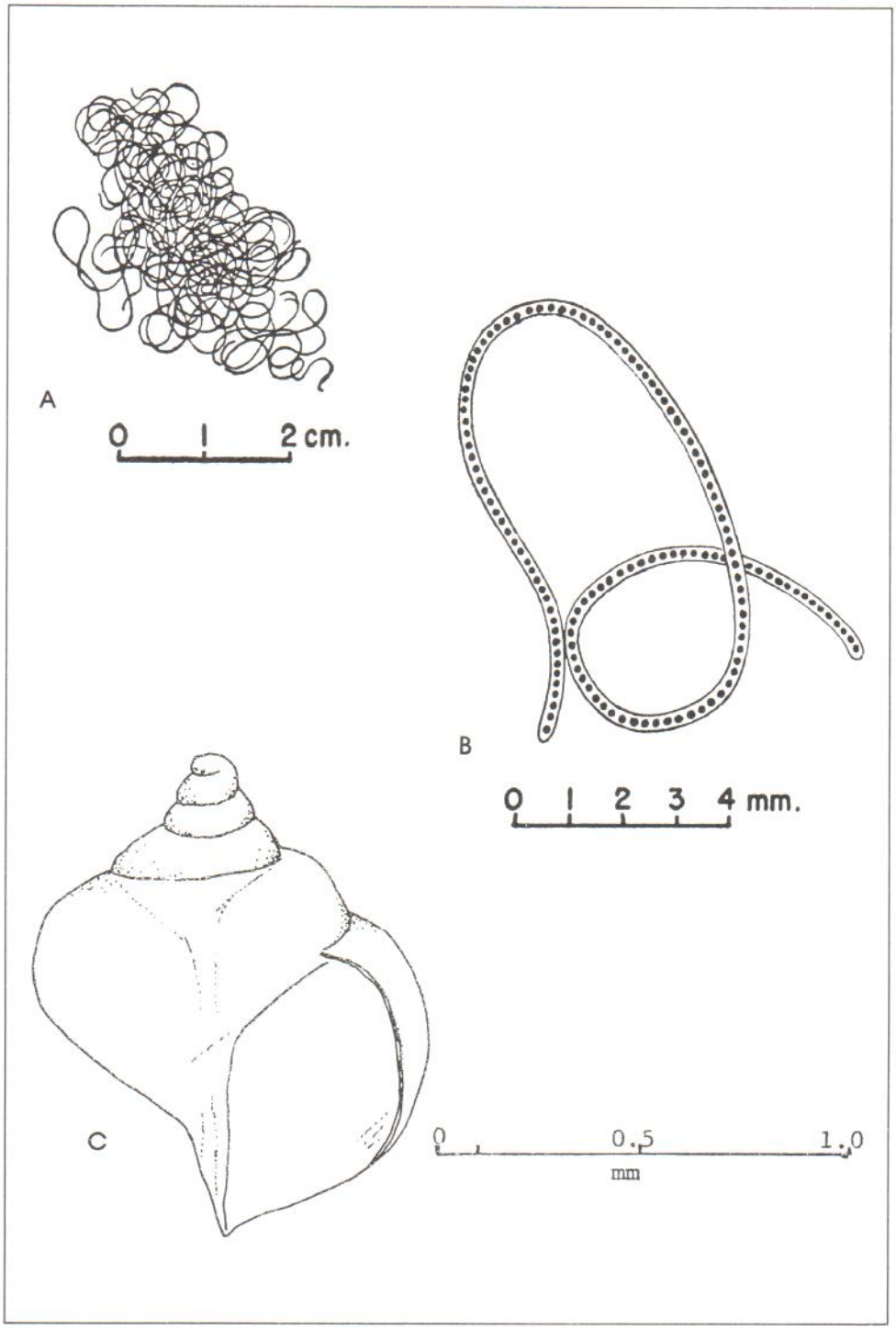


Figure 58.—Egg mass (A, B) and premetamorphic protoconch (C) of *Strombus maculatus*. (A and B from Ostergaard, 1950; C from J. B. Taylor, 1975.)

(Abbott, 1960; 1961). (Ostergaard's (1960) reports of *S. ostergaardi* from the Marshall Islands, Okinawa, and the New Hebrides have not been confirmed.)

Strombus dentatus Linnaeus, 1758. Fig. 59 H. (Synonym: *Strombus samar* Dillwyn, Morris, 1952.) Length, 35 mm; diameter, 13 mm. *Shell:* elongate; solid; axially plicate; with three or four toothlike projections at the base of the outer lip; glossy, maculated with brown and white. *Spire:* apical whorls attenuate; last whorl the largest; suture barely impressed. *Sculpture:* abapical whorls with 6 to 14 oblique, rounded, smooth axial folds; remaining whorls smooth. *Aperture:* elongate; outer lip thick, bearing three or four sharp, toothlike projections; stromboid notch obscured by the projections; columella with spiral lirae apically and abapically; interior of body whorl with 30 to 40 lirae. *Color:* cream, irregularly clouded or maculated with brown. *Animal:* mottled green; proboscis dark green with cream spots (F. Adams, 1967).

Living animals have been dredged at depths of 70 to 80 m. Fossil shells are found in Pleistocene reefs 500 feet above sea level on Lanai (Abbott, 1960).

S. dentatus ranges throughout the Indo-West Pacific from Mozambique and Zanzibar through Polynesia (Abbott, 1960).

Strombus erythrinus erythrinus Dillwyn, 1817. Fig. 59 J, K. Length, 32 mm; diameter, 16 mm. *Shell:* elongate; solid; somewhat rugose; white or marbled, aperture purple-brown. *Spire:* apical whorls attenuate, others angled by axial knobs; suture indistinct. *Sculpture:* apical whorls with incised spiral threads becoming cordlike on the later whorls; abapical whorls with angled knobs in addition to numerous, fine, crowded spiral cords. *Aperture:* elongate; stromboid notch shallow; columella with about 24 indistinct spiral lirae which are weak on the middle portion; inside of last whorl with 20 to 28 fine spiral threads. *Color:* variable — cream with lighter or darker brown suffusing the whorls, sometimes with two narrow chocolate bands.

This species is known only from specimens dredged at depths of about 40 m.

S. erythrinus erythrinus occurs from the Red Sea and East Africa to southern Japan and the Ellice Islands (Abbott, 1960).

Strombus fragilis (Röding, 1798). (Not figured.) Length, 35 mm; diameter, 14 mm. *Shell:* elongate-oval, smooth, thin-shelled; white with patches of orange-brown. *Spire:* 9 whorls, the apical attenuate and the last whorl the largest; suture barely impressed. *Sculpture:* none except for some microscopic, spiral incised lines on the apical whorls. *Aperture:* elongate; stromboid notch weak; columella with four or five weak spiral lirae at the base. *Color:* white with large, irregular patches of orange-brown.

S. fragilis is a rare deep-water species in Hawaiian waters, known only from occasional records of beachworn shells, and a record in the Academy of Natural Sciences, Philadelphia (Abbott, 1960).

This species occurs in the southwest Pacific, in the Ryukyu Islands, and Indonesia (Abbott, 1960).

Strombus helli Kiener, 1843. Fig. 59 A. (Synonym: *Strombus cancellatus* Pease, 1861a.) Length, 21 mm; diameter, 11 mm. *Shell:* rotund, solid; axially plicate with cancellate sculpture; white with a violet aperture. *Spire:* 9 to 10 whorls; apical whorls

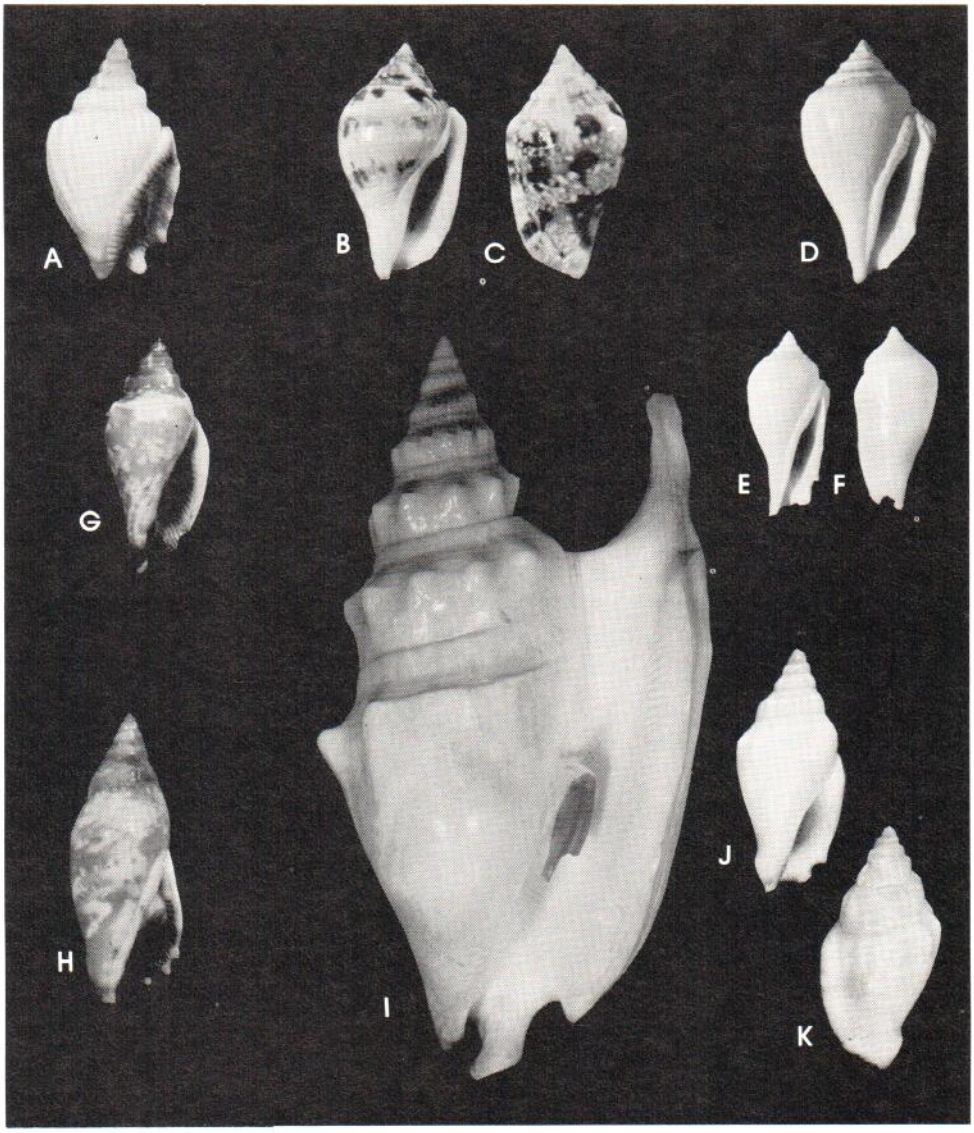


Figure 59.—**Strombidae.** A. *Strombus helli*, length 21 mm. B, C. *S. maculatus*, length 25 mm. D, E, F. *S. mutabilis ostergaardi*, length 30 mm. G. *S. wilsoni*, length 23 mm. H. *S. dentatus*, length 35 mm. I. *S. vomer hawaiensis*, length 100 mm. J, K. *S. erythrinus*, length 21 mm.

attenuate; last whorl rotund; suture barely impressed. *Sculpture:* small, crowded axial ribs forming pinched knobs on the last third of the last whorl; between the ribs a series of spiral threads, weak on the apical whorls, cordlike on the abapical whorls. *Aperture:* elongate; outer lip thin but strong, serrated; stromboid notch well-formed and flanked above and below by a flaring tonguelike flange or tooth; columella with about 24 wavy, spiral lirae. *Color:* usually white, sometimes mottled with various shades of brown; columella and aperture violet.

This species is common in dredge hauls at depths of 12 to 130 m, and dead shells were brought up by the *Albatross* from 480 m. Worn shells are occasionally found in drift along the northern beaches in the Hawaiian Islands.

S. helli is endemic to the Hawaiian Islands.

Strombus maculatus Sowerby, 1842. Figs. 58; 59 B, C. (Synonym: *Strombus maculatus* "Nuttall" Jay, 1839, *nomen nudum.*) Length, 25 mm; diameter, 14 mm. *Shell:* elongate, with swollen shoulders; cream with weak maculations of brown, aperture white. *Spire:* protoconch of four to four and one-half whorls; teleoconch of 8 to 9 whorls, the apical whorls convex, last whorl much the largest with the shoulders swollen; suture indistinct. *Sculpture:* apical whorls with spiral threads and/or weak nodules; last whorl with numerous microscopic spiral threads. *Aperture:* elongate; stromboid notch shallow; columella smooth at the center, with 3 to 7 spiral lirae apically and 1 to 10 near the base; interior of body whorl with 20 to 40 fine, raised spiral lirae; operculum stromboid, light brown, with 10 fine serrations. *Color:* cream with weak maculations and a fine network of yellow, orange-brown or gray-brown; periostracum transparent yellow.

This is the only commonly occurring stromboid in the Hawaiian Islands, found on intertidal solution benches and to depths of 2 m. *S. maculatus* moves in a series of short, leaping motions, and rights its overturned shell by kicking at the substratum with the operculum (Berg, 1971b). The presence of a molluscivorous *Conus* generates an escape response, the animals waving their tentacles, flipping the shell backward, and then moving rapidly away from the cone (Berg, 1971b). The egg masses are long, threadlike tubes agglutinated with sand grains. Veliger larvae are common in the plankton in Kaneohe Bay, Oahu, from March to September; the larvae hatch five to seven days after spawning and are probably planktonic for at least five weeks (J. B. Taylor, 1975). These gastropods probably reproduce within a year after settlement.

S. maculatus ranges through the Pacific from Micronesia and eastern Polynesia to Easter Island (Abbott, 1960). This species is much more abundant in the Hawaiian Islands and Marshall Islands than it is elsewhere in its range.

Strombus vomer hawaiensis Pilsbry, 1917. Fig. 59 I. (Synonym: *Strombus hawaiensis* Pilsbry, 1917.) Length, 100 mm; diameter, 50 mm. *Shell:* solid, high-spired and with a projecting upper and outer lip; knobbed; glistening cream, aperture white to yellow. *Spire:* apical whorls angulate; suture barely impressed. *Sculpture:* spiral and axial threads on apical whorls; abapical whorls with a spiral of knobs and with spiral threads. *Aperture:* elongate; stromboid notch deep; outer lip flaring and thick, with a projection at the top; columella with 10 to 15 spiral lirae on the base; operculum yellow-brown, thick, longitudinally furrowed, edge serrated. *Color:* cream to fawn, maculated and speckled with brown, aperture white to yellow. *Animal:* cream with light brown spots, proboscis brown with white spots (F. W. Adams, 1966).

These strombids are rarely found, buried deep in sand at depths of 26 m.

S. vomer hawaiensis is the endemic Hawaiian subspecies of a polytypic species which has two other forms, *S. v. vomer* recorded from the Ryukyu Islands and New Caledonia, and *S. v. iredalei* which is found from western Australia to the Gulf of Carpentaria. Abbott (1960) suggests that the species was once widespread in the Pliocene, and as its range became restricted, two peripheral populations survived as

isolated and distinct gene pools. Fossil shells identified as *S. aurisdianae* by Ostergaard (1928) may represent *S. vomer hawaiensis*.

Strombus wilsoni Abbott, 1967. Fig. 59 G. Length, 23 mm; diameter, 9 mm. *Shell:* elongate-quadrate, with short rounded nodules on the apical half of the last whorl; light yellow-brown. *Spire:* protoconch of three glassy, smooth, bulimoid whorls; teleoconch of eight or nine whorls. *Sculpture:* spire with 9 to 11 former varices, penultimate whorl with 15 to 22 minute, elongate axial ribs; last whorl with five to seven short, rounded, elongate nodules at the shoulder; varix behind outer lip swollen and with spiral threads. *Aperture:* narrowly constricted at posterior end; stromboid notch shallow, near the base of the outer lip. *Color:* white to cream, maculated with red-brown to tan and with spiral rows of small, sparse brown or white dots. Periostracum thin and translucent.

Shells of *S. wilsoni* are rare in the Hawaiian Islands, found at depths of about 25 m (Wolfe, 1973).

This species ranges from East Africa to Australia and Fiji (Abbott, 1967) and the Cook Islands and Marshall Islands (Wolfe, 1973).

Superfamily HIPPONACEA

The three families included in the Hipponacea (Hipponicidae, Fossaridae, and Vanikoridae) appear to be united as a matter of convenience rather than phylogeny. The single feature these gastropods seem to have in common is the taenioglossate radula; in both adult and protoconch shell form, and in habits, they are widely disparate. Members of the Hipponicidae have caplike or limpetlike shells which are fixed to the substrate and the protoconch is relatively large (0.5 to 1.0 mm in diameter) and neritoid or globose. The vanikorids and fossarids are free-living gastropods with turbinate shells and the protoconch is conical and small (300 to 400 μm in length).

Family **Fossaridae**

The shells of the fossarids are small and turbiniform, usually umbilicate and with a prominent protoconch. The last whorl is large, the aperture oblique, and the columella is connected to the outer lip; spiral sculpture predominates on the shells. The operculum is thin and horny, with an upstanding nucleus and open spiral.

Fossarus cumingii (A. Adams, 1855a). Fig. 60 E. (Synonym: *Fossarus ecphora* Pilsbry, 1917.) Length, 3 mm; diameter, 1.5 mm. *Shell:* turbiniform, globose, thin; with fine spiral cords and threads on the last whorl; white. *Spire:* protoconch of two brown whorls, the apical with fine axial ribs, the abapical with a spiral keel crossed by axial ribs and punctate spiral striae; teleoconch of four whorls, the apical whorls flattened and the last whorl much the largest. *Sculpture:* apical whorls with strong spiral keels becoming threadlike on the last whorl. *Aperture:* subcircular; umbilicus plicate. *Color:* white.

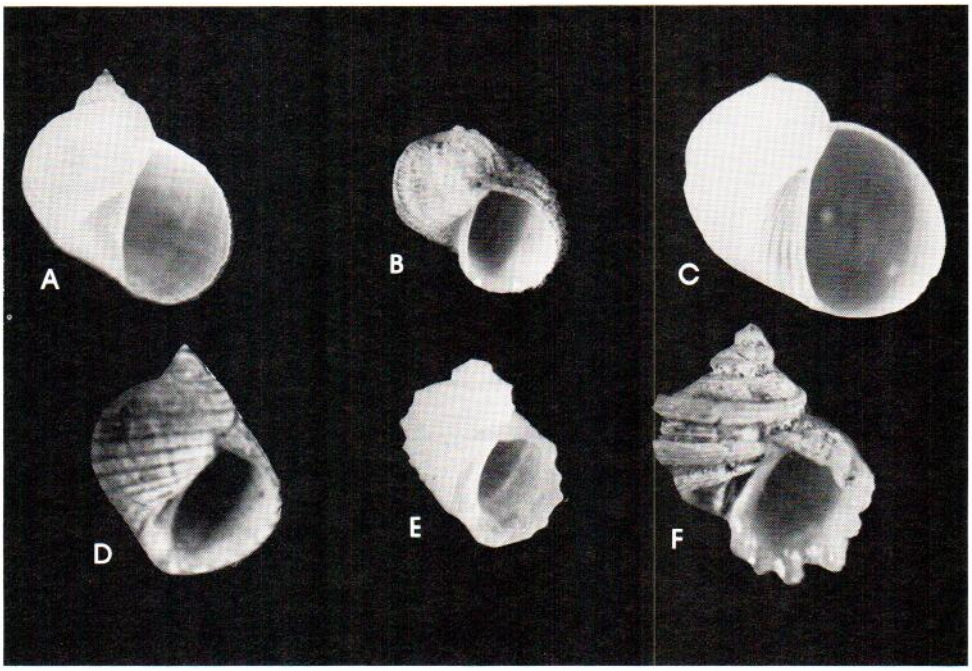


Figure 60.—**Vanikoridae** and **Fossaridae.** A. *Vanikoro imbricata,* length 6 mm. B. *V. cancellata,* length 10 mm. C. *V. acuta,* length 7 mm. D. *Fossarus multicostatus,* length 5 mm. E. *F. cumingii,* length 3 mm. F. *F. garrettii,* length 4 mm.

These animals are occasionally found under rocks or in crevices in tide pools; beachworn shells are common in drift.

No locality was designated in A. Adams's (1855b) description and the distribution of this species apart from its occurrence in Hawaiian waters is not known.

F. cumingii is distinguished from *F. garrettii* by its flatter spire and more weakly developed spiral sculpture.

Fossarus garrettii Pease, 1868. Fig. 60 F. (Synonym: *Adeorbis costata* Garrett, 1857, non Brocchi, 1814.) Length, 4 mm; diameter, 3.5 mm. *Shell:* turbiniform, solid; with prominent spiral keels; white. *Spire:* protoconch of two obliquely set brown, cancellate whorls; teleoconch of three whorls, the last the largest. *Sculpture:* three or four prominent spiral cords, the interspaces approximately one-third the diameter of the cords with fine spiral threads. *Aperture:* subovate, outer lip reflected outward; umbilicus narrow; base with a projecting flange separated from the columella which is reflected over it. *Color:* white.

Specimens are occasionally found under rocks in tide pools; beachworn shells are common in drift.

F. garrettii may be endemic to the Hawaiian Islands; it is distinguished from *F. trochlearis* (A. Adams, 1855a) from the Seychelles, Bombay, New Caledonia, and southern Japan by its more obtuse shape, shorter spire, wider, grooved keels, and regularly striate interspaces.

Fossarus multicostatus Pease, 1861a. Fig. 60 D. Length, 5 mm; diameter, 3 mm. *Shell:* turbiniform; thin; finely spirally striate; white. *Spire:* protoconch of three and one-half brown whorls, the apical one and one-half whorls smooth, the next with fine axial riblets, the abapical unicarinate and with axial threads; teleoconch of four inflated whorls; suture indistinct. *Sculpture:* spiral threads between which are weaker spiral striae. *Aperture:* oblique; base projecting as a moderate canal; neck striated; umbilicus moderately deep. *Color:* white.

These animals appear to be gregarious, five or more clustering together on the undersurfaces of rocks in shallow water. Beachworn shells are common in drift.

F. multicostatus was described from the Hawaiian Islands but is widely distributed in the Indo-West Pacific, from Réunion and the Persian Gulf to Tahiti.

Family **Vanikoridae**

The shell of the vanikorids is umbilicate, the last whorl is large and globose, and the protoconch is disproportionately small. The apical whorls are strongly sculptured, but the sculpture becomes obsolete on the last whorl. Because of the sculptural differences, several names have been introduced for each species, and the nomenclature of this group is unsatisfactory.

Little is known of the habits of these prosobranchs, except that they are epifaunal, living under rubble in tide pools or under large coral boulders at moderate depths.

Vanikoro acuta (Recluz, 1844). Fig. 60 C. (Synonyms: *Vanikoro semiplicata* Pease, 1861b; *V. kanakanarum* Pilsbry, 1921, *V. helicoidea* (Le Guillou, 1842), Cernohorsky, 1972, in part.) Length, 7 mm; diameter, 6 mm. *Shell:* globose, thin, fragile; last whorl spirally striated, apical whorls microscopically punctate; white. *Spire:* protoconch of two and one-half whorls, the apical whorls smooth, the abapical whorl with six to eight microscopically granular spirals; teleoconch of three or four globose whorls, the last whorl much the largest; suture indistinct. *Sculpture:* apical whorl with fine axial ribs between which are spiral striae producing a punctate effect, axial ribs becoming less noticeable on the subsequent whorls although the punctate effect remains apparent; last whorl finely striate. *Aperture:* subovate; columella shieldlike and straight; umbilicus deep and splaying out at the base, ridged with approximately ten keels; umbilical ridge finely crenulate, a groove separating it from the last whorl in juvenile specimens. *Color:* white.

Specimens are occasionally found beneath rocks in shallow waters; beachworn shells are numerous in drift.

This species was described from and is widely distributed through the Indo-West Pacific and has been recorded from the Moluccas and Lord Hood Island (Smith, 1908) and the Tuamotus (Dautzenberg and Bouge, 1933, as *V. semiplicata).*

Vanikoro cancellata (Lamarck, 1822). Fig. 60 B. Length, 10 mm; diameter, 8 mm. *Shell:* globose; with axial ribs crossed by spiral keels; white. *Spire:* three whorls plus the protoconch; the last whorl the largest; suture channeled. *Sculpture:* apical whorls and the last whorl with prominent axial ribs (about 20 on the last whorl) crossed by sharp spiral keels or cords alternately larger and smaller; ribs and interspaces of equal diameter, spiral threads of lesser diameter. *Aperture:* semicircular;

umbilicus deep, channel narrow and ridged. *Color:* white; periostracum yellow-brown, hairy.

V. cancellata occurs at depths of from 20 to 24 m.

This species is widespread in the Indo-West Pacific.

Vanikoro imbricata Pease, 1861b. Fig. 60 A. (Synonym: *Vanikoro distans* (Recluz, 1844), Cernohorsky, 1972, in part.) Length, 6 mm; diameter, 7 mm. *Shell:* globose, thin, fragile; last whorl with axial ribs and fine spiral striae; white. *Spire:* teleoconch of three and one-half globose whorls, the last whorl much the largest; suture distinct. *Sculpture:* apical whorls with fine axial ribbing, granulated where they are crossed by spiral threads; abapical whorls with closely spaced, curved axial ribs, with fine spiral striae in the intercostal spaces. *Aperture:* ovate, outer lip jutting forward at the base; base with a wide and deep umbilicus with axial ribs and spiral striae. *Color:* white.

Shells are occasionally found in beach drift but nothing is known of the habits of the living animal.

V. imbricata was described from the Hawaiian Islands. It is distinguished from *V. distans* (Recluz) by its smaller size and more closely spaced axial ribs.

Family **Hipponicidae**

The hipponicids are sedentary mesogastropods which live attached to rocks or other shells, some forming a distinct cavity in the substrate, others cemented with a shelly base. The shells are limpetlike and solid, with the apex somewhat posterior and directed backwards, and the muscle scar opens anteriorly. In some species there is a fibrous periostracum.

Although sessile, not all hipponicids are ciliary feeders as are capulids and calyptraeids, but several may extend the proboscis far beyond the margins of the shell, obtaining algae and detritus from the substrate or the fecal pellets of other gastropods by means of the radula.

Some hipponicids have been reported to be protandrous hermaphrodites, but all in the Hawaiian Islands appear to be bisexual. Hipponicids incubate their eggs in transparent oval egg capsules within the mantle cavity beneath the shell. All Hawaiian hipponicids have planktonic veliger larvae, but veliger life appears to be short, from several hours to a week (J. B. Taylor, 1975). The velum is bilobed in *Hipponix foliaceus, H. imbricatus,* and *H. pilosus,* and four-lobed in *Sabia conica.*

In the tropical Pacific hipponicids, except for *Sabia conica,* seem curiously restricted in their distribution to high islands; they are uncommon on atolls but well known from Samoa and Guam. In the Hawaiian Islands all four species are common along shorelines of the windward islands, but *H. foliaceus* has been found only at Laysan among the leeward islands, and *H. pilosus* occurs on La Perouse Pinnacle at French Frigate Shoals but not on the calcareous shoreline of the atoll, and *H. imbricatus* is unknown in the leeward islands.

Taxonomists do not agree on the use of the generic name *Hipponix,* the type of which is a fossil from the Eocene of France. Each of the four species reported here is considered to belong to a separate genus by Iredale (1937) and Morrison (1965), who

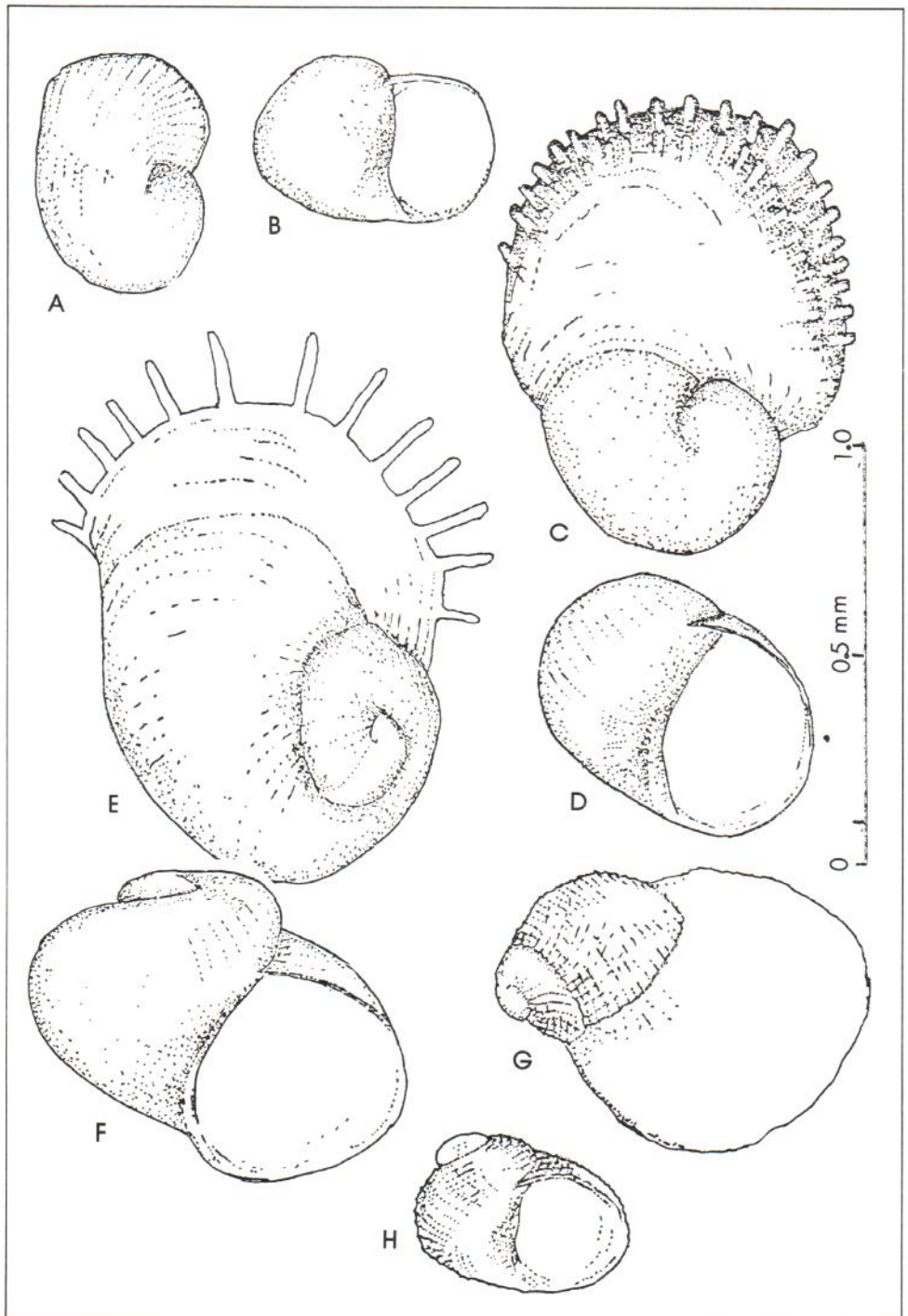


Figure 61.—**Hipponicidae.** A, B. Protoconchs of *Hipponix foliaceus*. C, D. Protoconch (D) and early teleoconch (C) of *H. imbricatus*. E, F. Protoconch (F) and early teleoconch (E) of *H. pilosus*. G, H. Protoconch (H) and early teleoconch (G) of *Sabia conica*. (From J. B. Taylor, 1975.)

distinguish the genera on the basis of differences in the protoconchs. Cowan (1974) also recognizes several genera in the family.

Hipponix (Antisabia) foliaceus (Quoy and Gaimard, 1835). Figs. 61 A, B; 62 C, D. (Synonym: *Hipponix antiquatus* Linnaeus, Tryon, 1886.) Length, 15 mm; diameter, 12 mm. *Shell:* limpetlike, oval, with concentric lamellae; apex projecting over posterior edge of shell; white. *Protoconch:* flattened-neritoid, of one and one-quarter whorls; apical whorl smooth, abapical whorls with spiral grooves; colorless to light tan. *Sculpture:* irregular, platelike, concentric lamellae and fine radial striae. *Color:* white; ventral shell margin often black. *Animal:* head, tentacles, and mantle white; foot white, edged with gray; tip of penis bifid (Cass, 1967).

These mollusks are common on the undersurfaces of rocks in tide pools and on fringing reefs; beachworn shells are abundant in drift. Veliger larvae are common in the plankton of Kaneohe Bay, Oahu in August (J. B. Taylor, 1975). Shells are common in the windward islands but found only on Laysan among the leeward islands.

H. foliaceus is reported from many localities in the Indo-West Pacific, and from the west coast of the Americas (Keen, 1971; Cowan, 1974).

Hipponix (Cochlear) imbricatus Gould, 1846. Figs. 61 C, D; 62 I, J. (Synonym: *Hipponix pilosus imbricatus* Edmondson, 1933.) Length, 11 mm; diameter, 6 mm; height, 9 mm. *Shell:* limpetlike, subcircular; apex posterior and central; with coarsely beaded ribs and sparse periostracal hairs; cream to light brown. *Protoconch:* flattened-neritoid; of one and one-half whorls; smooth, occasionally with faint spiral striae; colorless to light tan. *Sculpture:* radial ribs granulated by coarse spiral threads. *Color:* exterior cream to brown; interior margined with brown, white in the center. *Animal:* gray and brown; tip of penis club-shaped (Cass, 1967).

These limpets are common under rocks in tide pools and shallow bays and abundant on the algal ridge of fringing reefs. They are found only along the shorelines of the windward islands. The veligers may be planktonic for less than a week (J. B. Taylor, 1975).

H. imbricatus was described from the Hawaiian Islands. The shells resemble those of *H. grayanus* Menke, 1853, from the eastern Pacific.

Hipponix (Pilosabia) pilosus (Deshayes, 1832). Figs. 61 E, F; 62 A, B. (Synonym: *Hipponix barbatus* Sowerby, Edmondson, 1933.) Length, 18 mm; diameter, 8 mm; height, 15 mm. *Shell:* limpetlike, oval; apex posterior; with fine radiating ribs and granular spiral striae between which project the bristlelike hairs of the periostracum; margins slightly crenulated; cream. *Protoconch:* globose-depressed; of two and one-half smooth brown whorls. *Sculpture:* fine radiating ribs equal in diameter to the interspaces, the ribs crossed by concentric threads which are nodulated at the junctions of their ribs. *Color:* cream; interior sometimes stained with brown. Periostracum dense and hairy, projecting beyond the anterior lip of the shell. *Animal:* head, tentacles and mantle white; foot edged with gray; tip of penis club-shaped (Cass, 1967).

Specimens are common under rocks in shallow bays and on fringing reefs in the windward islands but are found only on Gardner Pinnacles in the leeward islands. The veligers may be planktonic for at least a week (J. B. Taylor, 1975).

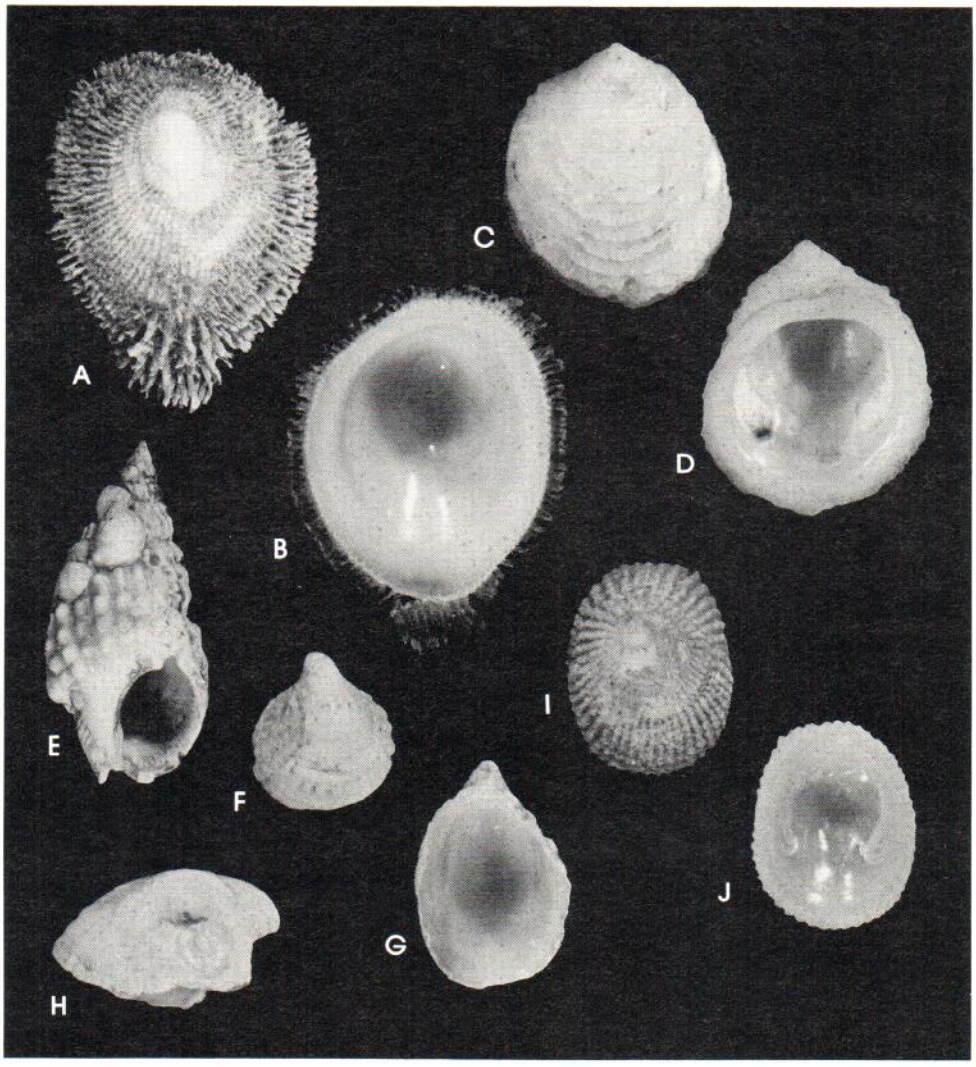


Figure 62.—**Hipponicidae.** A, B. *Hipponix pilosus,* length 18 mm. C, D. *H. foliaceus,* length 15 mm. E. *Sabia conica* on *Nassarius papillosus.* F, G, H. *S. conica,* length 10 mm. I, J. *Hipponix imbricatus,* length 11 mm.

H. pilosus occurs in both the tropical Atlantic and the tropical eastern Pacific from the Gulf of California to Ecuador (Keen, 1971).

Sabia conica (Schumacher, 1817). Figs. 61 G, H; 62 E-H. (Synonym: *Hipponix minor* Garrett, 1853.) Length, 9 mm; diameter, 7 mm; height, 5 mm. *Shell:* limpet-like, conical; apex prominent and peaked, forming a distinct cone posteriorly which overhangs the margin; margins scalloped; cream and brown. *Protoconch:* globose; of two and one-half brown whorls at right angles to the axis of the teleoconch; whorls with fine, cancellate sculpture. *Sculpture:* flat, radiating ribs, the interspaces narrow

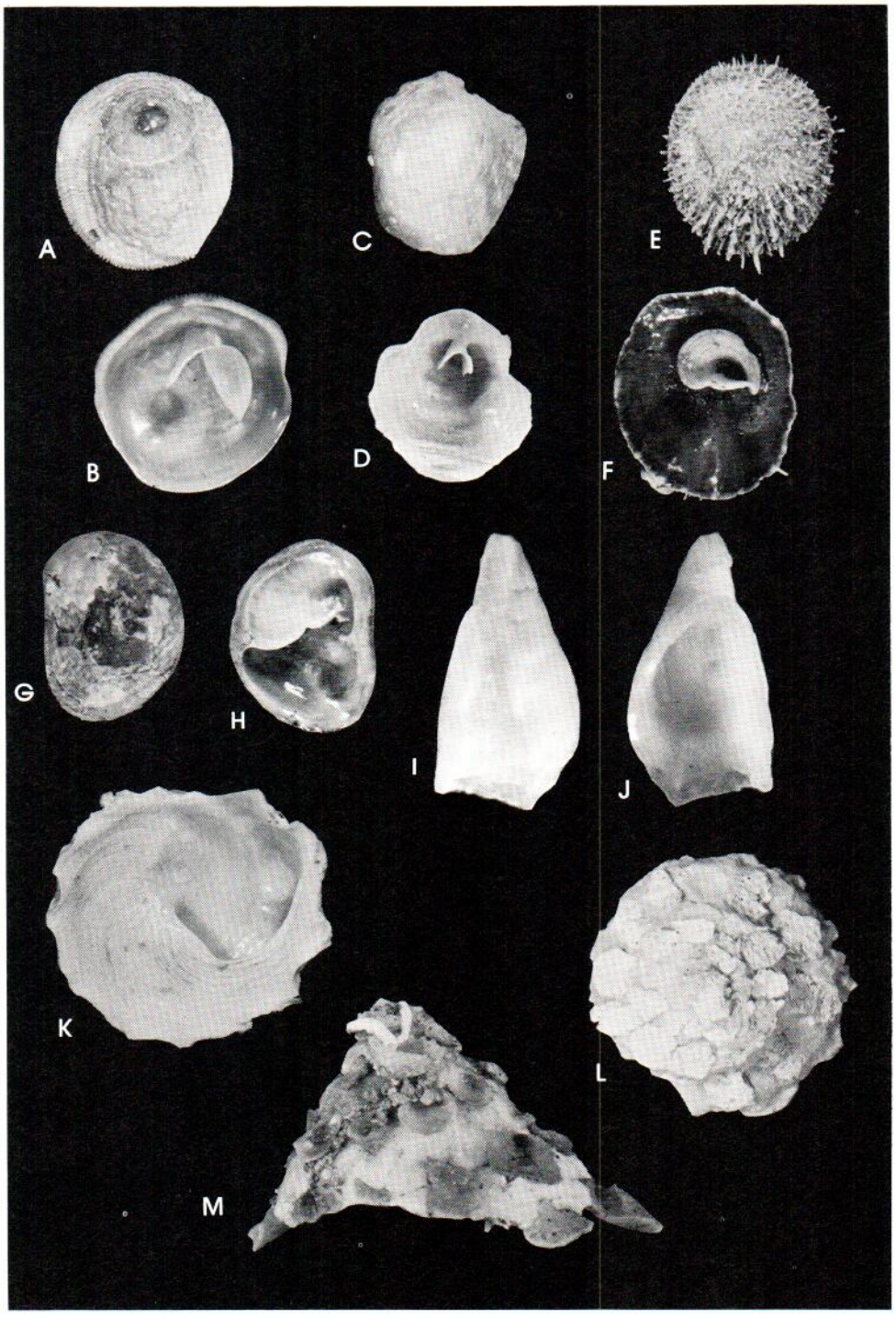


Figure 63.—A - D. *Cheilea equestris*. A, B. rough form, diameter 25 mm. C, D. smooth form, diameter 20 mm. E, F. *Crucibulum spinosum*, length 12 mm. G, H. *Crepidula aculeata*, diameter 20 mm. I, J. *Capulus bicarinatus*, length 5 mm. K, L, M. *Xenophora peroniana*, length 30 mm.

and punctate; old shells often rugose and wrinkled. *Color:* cream with brown markings in the grooves; interior porcelaneous white, streaked with maroon and brown.

These hipponicids live attached to gastropods such as *Turbo, Terebra,* and *Conus* where they leave a conspicuous scar usually near the aperture of the host shell. The animals may feed on the fecal pellets of their hosts (Yonge, 1953). Small shells, possibly males, are often found on larger shells which are presumably females. The veliger larvae appear to be planktonic for at least a week (J. B. Taylor, 1975). They are recorded from all islands in the Hawaiian chain.

S. conica occurs throughout the Indo-West Pacific, and has also been reported from south Australia (H. M. Laws, 1970) and the west coast of the Americas (Keen, 1971).

Superfamily CALYPTRAEACEA

The members of the two families in this group of mesogastropods found in Hawaiian waters, the Capulidae and Calyptraeidae, are limpetlike in habit, but the apex of the shell is spirally coiled. They are, for the most part, ciliary feeders, with the mantle cavity modified in assocation with this habit: it is very long, the gills are extensive with long filaments, and there is a great deal of mucus production. Reproduction in calyptraeaceans is also related to their limpetlike habit; many are protandrous hermaphrodites, changing during the course of their life histories from small males into full-grown females.

Family **Calyptraeidae**

Calyptraeid shells are low and conical, distinguished by the presence of an internal shelf or deck. Calyptraeids are sessile ciliary feeders, and they brood their young. Two genera are represented in Hawaiian waters: *Crepidula,* the slipper shell, with a flat deck across one half of the shell aperture, and *Crucibulum,* the cup and saucer limpet, with an internal, cuplike projection.

Cheilea equestris (Linnaeus, 1758). Fig. 63 A-D. Diameter, 25 mm; height, 10 mm. *Shell:* limpetlike, circular and conical but with a wide range of shape because of the sessile habit; apex nearly central; margins crenulate and undulate; interior with a spiral diaphragm thickened basally and attached at the apex. *Protoconch:* neritoid, light brown, smooth or obliquely cancellate. *Sculpture:* exterior with fine radiating ribs crossed by spiral threads, the junctions sharply nodular; interior polished.

This calyptraeid is rarely found in shallow water but is common at depths of from 50 to 400 meters.

C. equestris is generally considered to be circumtropical in distribution, occurring on both sides of the Americas and through the Indo-West Pacific. The shells are variable in texture, shape, and sculpture, and many names have been used, some forms of which may represent good species.

Crepidula aculeata (Gmelin, 1791). Fig. 63 G, H. Length, 18 mm; diameter, 13 mm; height, 4 mm. *Shell:* oval, low, domelike; apex lateral and posterior; columella expanded as a shelf which covers the posterior half of the aperture. *Sculpture:*

radiating ribs, some of which may be roughened. *Color:* variable — yellow or brown, often with brown rays. *Animal:* uniform buff, head and mantle with opaque white spots; posterior portion of the foot attached to the shell but the anterior section is extremely mobile and the animal can right itself by means of its extended foot.

Crepidula is a commonly occurring gastropod on boat bottoms, pilings, and rocks, especially near harbors. The sculpture of the shell often takes the form of the substrate. This species ranges round the world.

Crucibulum spinosum (Sowerby, 1824). Fig. 63 E, F. Length, 12 mm; diameter, 9 mm. *Shell:* low-conical; apex posterior; with an internal cuplike projection; surface wrinkled and/or spiny; gray-white. *Sculpture:* radial and spiral striae which are produced as knoblike or spiny projections where they meet. *Color:* gray-white, sometimes yellow, purple, or black.

These limpets are especially common in bays such as Kaneohe Bay, Oahu, and harbors, where they are found on coral rubble and basalt rocks at depths of from 5 to 8 meters. In a population of *Crucibulum* in Kaneohe Bay, the shape and ornamentation of the shells vary with the habitat: if individuals are crowded the apical angle of the shell is less than it is where they are well spaced, the shells are thin and the spines long and delicate; individuals on exposed rocks have thick, encrusted shells with moderate ornamentation (Ulbrick, 1969). Although the animals may remain stationary for several days, they can move about, movement in the male chiefly associated with mating, that in the female with spawning (Ulbrick, 1969). *C. spinosum* collects food in suspension and also rasps it from the substrate with its radula.

These gastropods spawn throughout the year in Kaneohe Bay and account for 90 to 95 percent of the veliger component in the bay in certain areas (J. B. Taylor, 1975). Most veligers remain in the plankton for a minimum of three weeks and a probable maximum of eight weeks.

C. spinosum is circumglobal in distribution and may have been introduced in Hawaii during World War II.

Family **Capulidae**

The capulids exhibit a variety of habits: some species of *Capulus* are ciliary feeders and another (*Capulus danieli* Crosse) bores a hole in its host, the pecten *Comptopallium vexillum* (Orr, 1962). Most members of the family have simple, somewhat irregular, cap-shaped shells which often take the form of the substrate to which they are attached.

Capulus bicarinatus (Pease, 1861a). Fig. 63 I, J. Length, 5 mm; diameter, 2 mm. *Shell:* triangularly ovate, thin, apex posterior; with two prominent radiating ribs; white. *Sculpture:* irregular radiating ribs diverging from the apex, two of which are more prominent than the others, and with fine, closely spaced, concentric striae. *Color:* white.

These capulids live on the oyster *Ostrea sandvicensis*, the ribs of the capulid shell matching the flutings of the oyster shell.

C. bicarinatus was described from the Hawaiian Islands, and has been reported from the Tuamotus (Dautzenberg and Bouge, 1933).

Family **Xenophoridae**

The Xenophoridae are so-called because of their remarkable habit, cementing to their shells empty shells of other mollusks, pebbles, and/or sand grains, a habit which has apparently remained unchanged since the Cretaceous. The cemented materials are successively attached in spiral sequence as the shell grows and embedded or surrounded in shell during its secretion by the mantle (Morton, 1958).

The shells of the xenophorids are trochiform with a wide peripheral keel and flat or concave base; in *Xenophora* the umbilicus is closed and the operculum smooth. These gastropods apparently live at moderate depths and in deep water. The animal of a species of *Xenophora* studied in New Zealand (Morton, 1958) displayed several adaptations which may be associated with life in heavily silted substrata: powerful currents in the mantle cavity function in keeping the cavity free of silt, the digestive system is such that it deals with organic matter from muddy silt, and locomotion is of the leaping type characteristic of other gastropods that live in soft substrata, such as *Strombus*.

Xenophora peroniana (Iredale, 1929c). Fig. 63 K-M. Length, 30 mm; diameter, 36 mm. *Shell:* trochiform; with a wide peripheral keel bearing attached shells and gravel; white. *Spire:* four or five straight-sided, sloping whorls; suture channeled. *Sculpture:* fine curved axial ribs imbricated with spiral threads; peripheral keel and suture with short projections to which are attached empty molluscan shells. *Aperture:* narrow and elongate; base concave, umbilicate in juvenile shells. *Color:* white.

X. peroniana occurs at depths of from 20 m to well over 400 m; uncommon from 20 to 60 m, the species appears to be most abundant at greater depths. In addition to gravel, single valves of the bivalve *Glycymeris* are most commonly attached to the shells.

This species was described from New South Wales at depths of from 120 to 140 m.

Superfamily LAMELLARIACEA

Family **Lamellariidae**

The lamellarids are perhaps the only prosobranch family with an internal shell, the mantle of these mollusks completely enclosing a transparent, white, caplike shell. The shell (Fig. 64) is few-whorled, with a periostracum, the outer lip sharp-edged, the inner lip smooth and slightly reflected. The mantle, on the other hand, is elaborately colored and sculptured, in some instances resembling the encrusting, compound ascidians on which these mollusks feed.

A striking feature in the life history of lamellarids is the occurrence of an echinospira larva, a planktotrophic veliger which is essentially double-walled, that is, the protoconch is surrounded by a scaphoconch, the latter often elaborately sculptured. Fretter and Graham (1962) suggest the scaphopod represents the periostracum of the shell, separated by a layer of extra-pallial fluid. Echinospiras also occur in *Capulus*

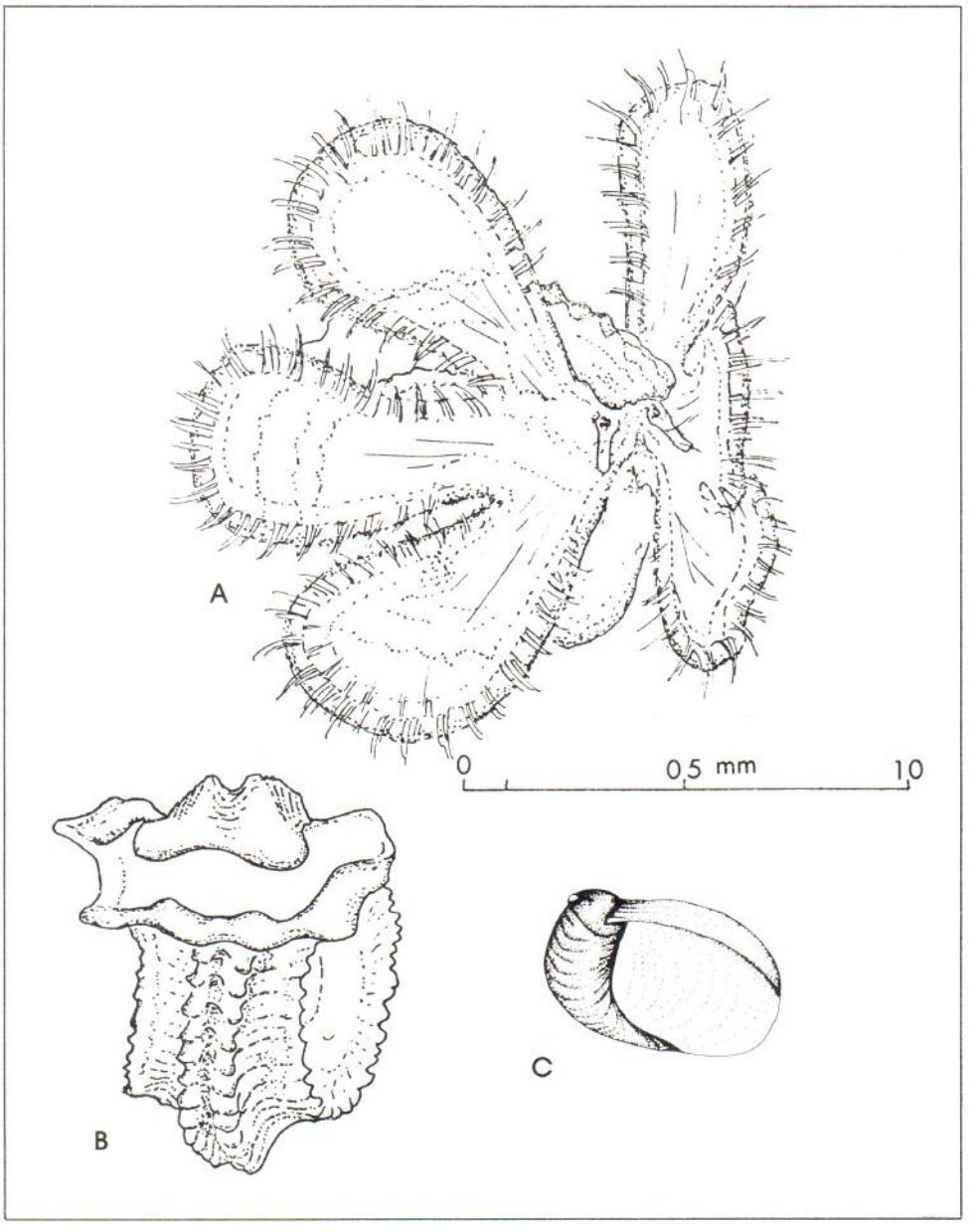


Figure 64.—**Lamellariidae.** A. Swimming veliger of *Lamellaria* sp. B. Scaphoconch, ventral view, *Lamellaria* sp. C. Shell, *Lamellaria* sp., length 7 mm. (A, B from J. B. Taylor, 1975; C by R. Kawamoto.)

and the Eratoidae. In *Lamellaria* coiling of the larval shell is nautiloid or involute (Fig. 64); in the eratoids it is helicoid.

The echinospiras of three species of lamellarids have been described from the plankton of Hawaiian waters (J. B. Taylor, 1975) but records of adults are sparse: one

living snail resembling a yellow tridemnid tunicate was collected at a depth of 10 m off Barbers Point, Oahu, in 1965 and several shells are known from beach drift. Until additional material is available, no names can be assigned the Hawaiian species.

Superfamily TRIVIACEA

These gastropods have been associated with the Cypraeacea because of the shape of their shells, and the Lamellariacea because of the echinospira larva and their methods of feeding. Schilder and Schilder (1938) accorded them separate status because of the short pedal ganglion and semilunar osphradium. The echinospira of *Trivia* is helicoid, distinct from the naticoid form in lamellariaceans. *Trivia* and *Erato* are associated with compound ascidians, feeding by inserting their long proboscis into the zooids.

Family **Eratoidae**

The Eratoidae are separated into two subfamilies, the Eratoinae with smooth or pustular, pyriform shells, and the Triviinae with corrugated, ovate shells. The members of both groups are associated with compound ascidians; they feed by inserting their long proboscis into the zooids and deposit their eggs in vaselike capsules in the integument of the ascidian.

The Hawaiian species may be keyed as follows (modified from Schilder, 1933):

1. Shell corrugated; ovate 2
   Shell smooth; pyriform ..... *Erato sandwicensis*

2. (1) Subrostrate to cylindrical; white or pink 3
   Globular; extremities blunt; white ..... *Trivia globosa pilula*

3. (2) Dorsal sulcus distinctly impressed 4
   Dorsal sulcus absent, or if present only slightly impressed 5

4. (3) Dorsal sulcus narrow, long, usually entirely interrupting the ribs ..... *T. hordacea*
   Dorsal sulcus broad, short, mostly crossed by ribs ..... *T. edgari*

5. (3) Dorsal sulcus absent; shell white ..... *T. pellucidula*
   Dorsal sulcus often impressed; shell pink ..... *T. exigua*

Erato sandwicensis Pease, 1860. Fig. 65 F. Length, 5 mm; diameter, 3 mm. *Shell:* pyriform, solid, spire projecting, smooth; white clouded with brown. *Aperture:* narrow, labial denticles close-set; anterior end of columella distinctly denticulate, the denticles becoming minute apically and gradually obsolete. *Color:* shining blue-white with a broad band of yellow-brown on the abapical portion of the body whorl and a narrower band of the same color bordering the suture beneath. *Animal:* mantle pus-

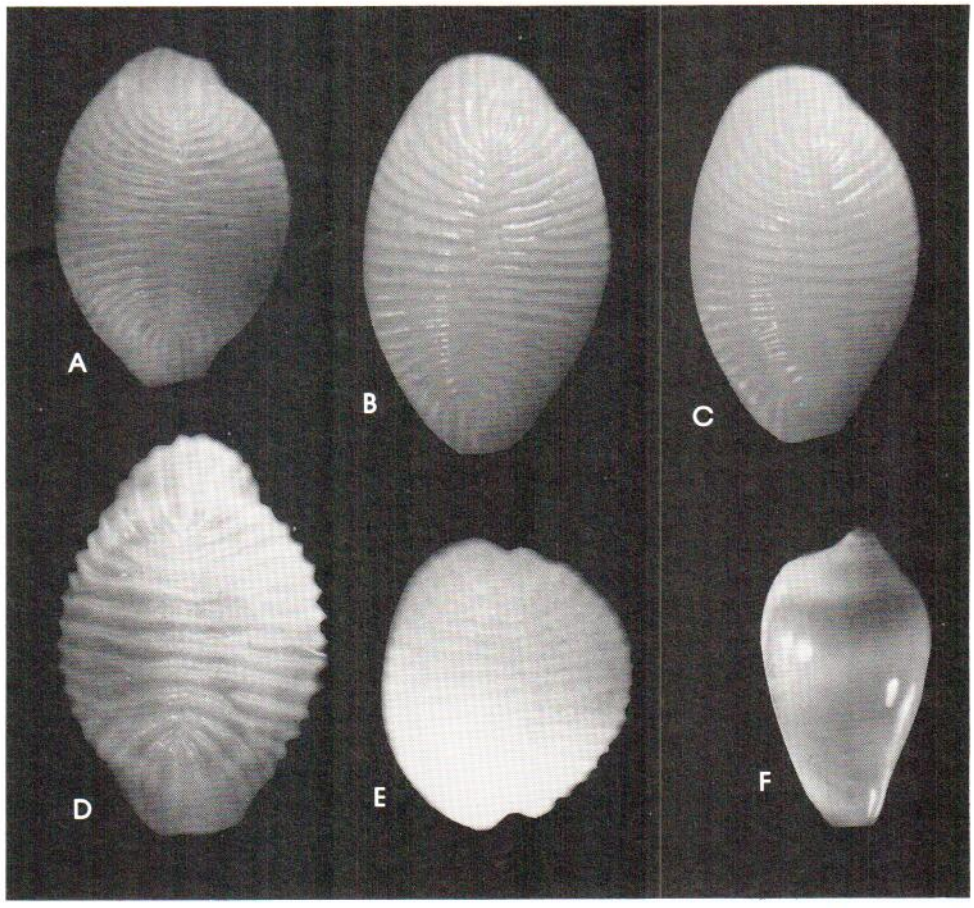


Figure 65.—**Eratoidae.** A. *Trivia edgari*, length 5 mm. B. *T. hordacea*, length 3.5 mm. C. *T. pellucidula*, length 5 mm. D. *T. exigua*, length 4 mm. E. *T. globosa pilula*, length 3 mm. F. *Erato sandwicensis*, length 4 mm.

tular, creamy yellow with black spotting and occasional splashes of red-orange especially apparent on the proboscis and foot.

Although beachworn shells are abundant in drift, living animals are only occasionally encountered on both gray and white compound ascidians which grow on the undersurfaces of rocks in shallow waters shoreward of fringing reefs.

This species was described from the Hawaiian Islands, but similar shells are found in the Seychelles, New Caledonia, and the Tuamotus.

Trivia edgari Shaw, 1909. Fig. 65 A. (Synonyms: *Trivia sandvichensis* Sowerby, 1870, *nomen nudum; T. oryza* Lamarck, Sowerby, 1870.) Length, 7 mm; diameter, 5 mm; height, 4 mm. *Shell:* ovate, extremities produced and blunt; dorsal sulcus impressed, broad and shallow, crossed by ribs; white. *Sculpture:* ribs parallel and equidistant, continuous across dorsum. *Aperture:* wide, straight. *Color:* white. *Animal:* mantle white with black smudges, papillae both single and branched; foot, tentacles,

and proboscis pale yellow-orange, dorsal surface of the foot with a network of yellow and white.

Although beachworn shells are common in drift, these mollusks appear to live at moderate depths of from 10 to 30 m.

T. edgari is of widespread distribution in the Indo-West Pacific (Allan, 1956).

Trivia exigua Gray, 1831. Fig. 65 D. (Synonyms: *Trivia gemmula* Gould, 1845; *T. tremeza* Duclos, Edmondson, 1933.) Length, 5 mm; diameter, 3 mm; height, 3 mm. *Shell:* short, ovate, extremities beaked and produced; dorsal sulcus variable; white blotched with pink. *Sculpture:* coarse, ribs crossing the dorsal sulcus if it is present, some of them bifurcate. *Aperture:* straight, curving anteriorly. *Color:* dorsum and sides blotched with pink, base white.

Shells are uncommon in beach drift and the habits of the living animal are unknown.

T. exigua has been recorded from various localities in the Indo-West Pacific.

Trivia globosa pilula Kiener, 1843. Fig. 65 E. (Synonyms: *Cypraea sphaerula* Mighels, 1845; *C. corrugata* Pease, Melvill, 1888.) Length, 3 mm; diameter, 2.5 mm; height, 2.5 mm. *Shell:* globular, extremities blunt; dorsal sulcus deep; white. *Sculpture:* nearly straight, parallel and equidistant ribs descending from either side of the dorsal sulcus and crossing the base. *Aperture:* narrow, curved. *Color:* white.

T. globosa is known from beachworn shells only; these are uncommonly found in drift along the beaches of both the north and south coasts of Oahu and Kauai.

T. globosa is widespread throughout the Indo-West Pacific; Schilder (1932) distinguishes the Central Pacific form from those occurring along the coasts of Asia and in the Indian Ocean.

Trivia hordacea Kiener, 1845. Fig. 65 B. (Synonyms: *Cypraea australis* Gray, 1828; *C. insecta* Mighels, 1845.) Length, 4 mm; diameter, 2.5 mm; height, 2 mm. *Shell:* elongate-ovate, subrostrate; dorsal sulcus impressed, ribs discontinuous; white. *Sculpture:* fine, equidistant ribs, some bifurcating on the sides, interrupted on the dorsum by the sulcus. *Aperture:* narrow, straight. *Color:* white. *Animal:* mantle thin, white clouded with black, sparsely papillate with simple papillae; proboscis with milk white and pink; foot white with a network of spicules.

This is the most commonly occurring of Hawaiian trivias; living animals are common in tide pools and under rocks in shallow waters shoreward on fringing reefs, and beachworn shells are abundant in drift.

T. hordacea occurs throughout the Indo-West Pacific (Allan, 1956).

Trivia pellucidula Reeve, 1846. Fig. 65 C. Length, 5 mm; diameter, 4 mm; height, 3 mm. *Shell:* globose, extremities produced and blunt; no dorsal sulcus, the ribs continuous over the dorsum; white. *Sculpture:* ribs straight, equidistant, extending over the dorsum to the sides and base. *Aperture:* narrow, straight but curved posteriorly. *Color:* white.

Shells of *T. pellucidula* are common in beach drift but are not so abundant as are those of *T. hordacea;* the habits of the living animals are not known.

T. pellucidula occurs throughout the Indo-West Pacific (Allan, 1956).

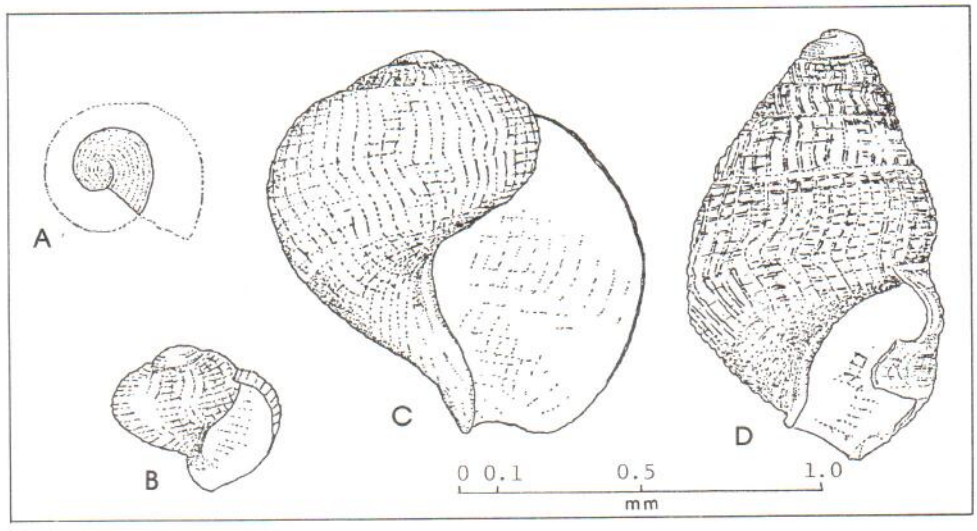


Figure 66.—A, B, C. Capsular (A), intermediate (B) and premetamorphic (C) protoconchs of *Cypraea fimbriata*. D. *C. isabella*, premetamorphic protoconch. (From J. B. Taylor, 1975.)

Superfamily CYPRAEACEA

The superfamily Cypraeacea includes two families, the Cypraeidae and the Ovulidae. The members of both families have polished shells with a long, narrow aperture, a ladderlike pedal ganglion, and a triradiate osphradium. They lack an echinospira larva. The Cypraeidae are less specialized than the Ovulidae, and most cypraeids are herbivores or omnivores; the ovulids are associated with corals.

Family **Cypraeidae**

The cowries are among the best known of all mollusks, their highly polished, elaborately patterned shells long prized in collections.

In habitat cowries range from the intertidal to depths of about 100 m. In feeding habits they are herbivores, omnivores and sponge feeders. *Cypraea caputserpentis*, the most common of the Hawaiian cowries, is largely herbivorous but some subtidal species rasp at detritus and sponge in coral heads.

Cowries deposit their eggs in triangular capsules which are attached to the substratum and the female "broods" the egg mass, enveloping it with her foot. Intracapsular development is from one to two and one-half weeks, after which the four-lobed veligers become planktotrophic (J. B. Taylor, 1975). As the veligers become planktonic, the protoconch becomes sculptured with axial and spiral threads (Fig. 66). Presettlement protoconchs of the Hawaiian cowries have from two and one-half to five and one-half whorls and are colorless to red-brown (J. B. Taylor, 1975).

Juvenile shells differ from adult cowry shells in that the juveniles are oliviform with only a thin columellar lip and a projecting spire. The color pattern of the adult cowry is not deposited until both labial and columellar lips begin to form.

Thirty-four species of *Cypraea* are recorded here; 24 are distributed throughout the Indo-West Pacific, five are restricted in their distribution to the Pacific basin, and five are apparently endemic to the Hawaiian Islands. The endemics appear to be more closely related to widespread Indo-West Pacific species than to those which occur only in the Pacific basin (Kay, 1967a).

In the following account only the genus *Cypraea* is recognized. More than 80 cowry names have been attributed to the Hawaiian Islands. While some of these records were the result of the erroneous interpretation of species (for example, the *Cypraea guttata* reported by Bloxam (1826)) and some have now fallen into synonymy *(C. alleni, C. annae, C. polita),* other names were based on specimens which reached the Islands via whaling and missionary ships which plied the Pacific in the 19th century. Baldwin's (1898) list, for example, includes such species as *C. argus, C. errones,* and *C. ventriculus,* all well known elsewhere in the Pacific, but which do not occur in Island waters.

I have been conservative in the use of subspecific names, utilizing only those that are founded on a statistical basis. Acceptance of all the subspecies proposed by Schilder and Schilder (1938-1939) and C. N. Cate (1965) implies some geographic relationships which differ from those supplied by analysis of other mollusks. Most of the subspecies are included in the list of synonyms.

Cypraea beckii Gaskoin, 1836. Fig. 67 A, B. Length, 11 mm; diameter, 6 mm; height, 5 mm. *Shell:* elongate-ovate; creamy yellow with cream-colored spots ocellated with chestnut. *Sides:* rounded. *Aperture:* narrow, straight; teeth small, columellar teeth extending on to base. *Color:* dorsum creamy yellow sprinkled with large and small circular white spots ocellated with chestnut; sides white, dotted with brown; base white, teeth brown.

Specimens are rare in Hawaiian waters. The few live-collected animals were usually found in the base of the black coral, *Antipathes grandis,* at depths of about 58 m (Weaver, 1965a). Two or three shells have been found in beach drift.

C. beckii occurs in the Pacific, in Japan, the Philippines, and the Marshall Islands.

Cypraea caputserpentis Linnaeus, 1758. Fig. 67 O, P. (Synonyms: *Cypraea caputanguis* Philippi, Melvill, 1888; *C. caputcolubri* Kenyon, 1898; *C. caputserpentis caputophidii* Schilder and Schilder, 1939.) Length, 30 mm; diameter, 22 mm; height, 14 mm. *Shell:* broadly oval; solid; dorsum reticulated brown and white, sides brown. *Sides:* sloping. *Aperture:* wide, curved posteriorly, dilated anteriorly; teeth extending partially on to base. *Color:* dorsum reticulated brown and white, often with a white mantle line; sides deep brown, base lighter; teeth white, interstices dull orange. *Animal:* mantle olive-brown splashed with yellow and green; papillae conical and dendritic usually tipped with red.

These cowries are the commonest species in the genus in the Hawaiian Islands, and are found in shallow water under loose rocks and boulders along the shoreline and in crevices at the seaward edge of solution benches and fringing reefs. *C. caputserpen-*

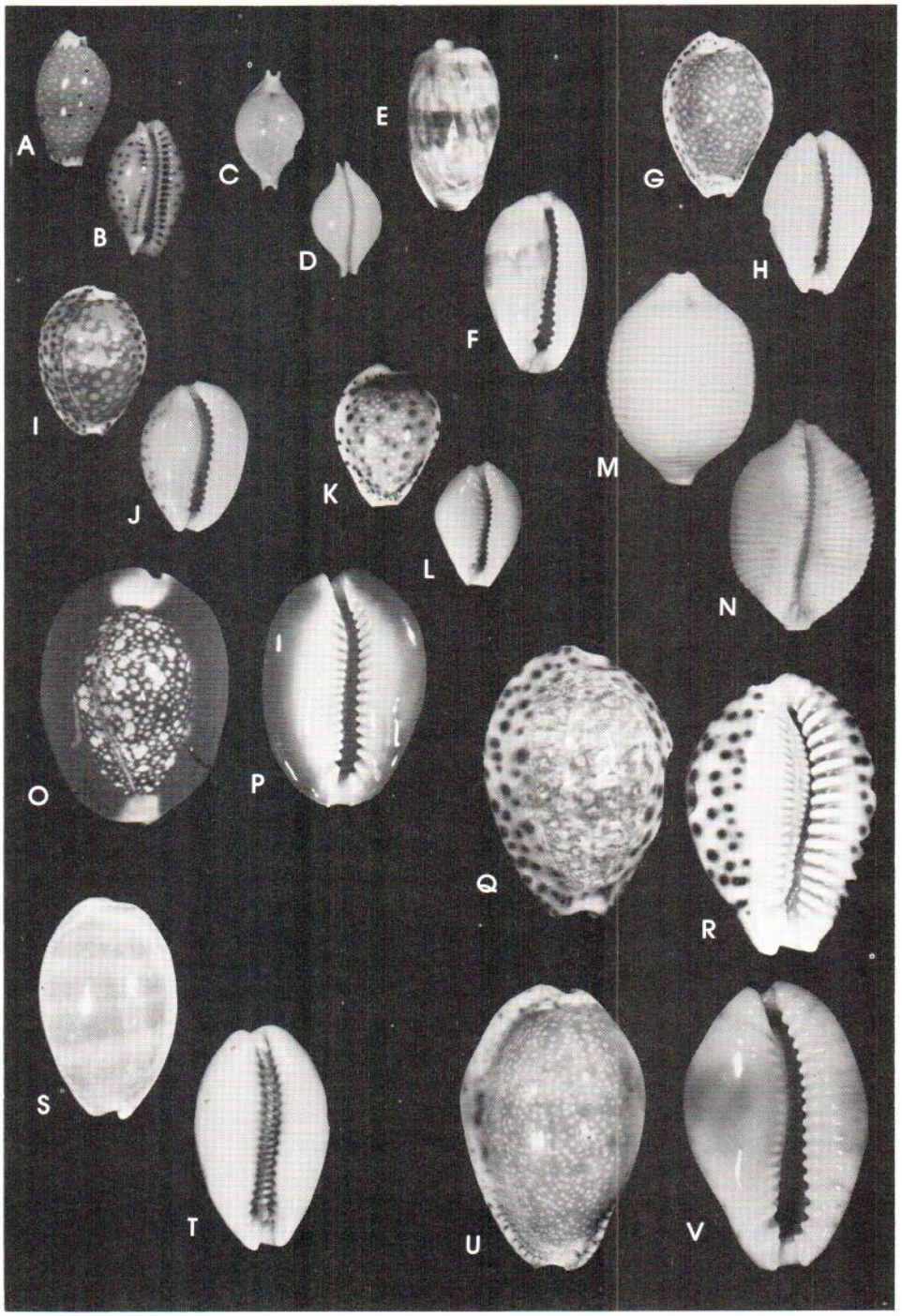


Figure 67.—**Cypraeidae.** A, B. *Cypraea beckii,* length 11 mm. C, D. *C. cicercula,* length 20 mm. E, F. *C. fimbriata,* length 12 mm. G, H. *C. cernica,* length 20 mm. I, J. *C. helvola,* length 22 mm. K, L. *C. poraria,* length 19 mm. M, N. *C. childreni,* length 25 mm. O, P. *C. caputserpentis,* length 30 mm. Q, R. *C. chinensis,* length 33 mm. S, T. *C. carneola,* length 34 mm. U, V. *C. erosa,* length 30 mm.

tis has been reported from Pleistocene fossil deposits on Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1928).

The Hawaiian shells are distinguished from Indian Ocean and Pacific Ocean forms by their shorter length, relatively greater height, larger number of teeth, narrower aperture, darker base and teeth interstices, and anterior terminal spots (Griffiths, 1959).

Cypraea carneola Linnaeus, 1758. Fig. 67 S. T. Length, 34 mm; diameter, 19 mm; height, 15 mm. *Shell:* cylindrical-ovate; red-brown with darker bands on the dorsum. *Sides:* sloping. *Aperture:* wide, straight; teeth short, not extending across the base. *Color:* dorsum red-brown crossed by four transverse darker bands; sides cream tinted with lavender; interstices of teeth purple. *Animal:* mantle red-brown; papillae conical, light red-brown; proboscis and tentacles yellow; foot dark brown.

These cowries occur in moderately deep water, at depths of four to twenty m, usually in areas where there is barren, dead coral. *C. carneola* has been reported in Pleistocene fossil deposits on Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939).

C. carneola is distributed throughout the Indo-West Pacific. Schilder and Schilder (1939) and C. N. Cate (1965) distinguish the Hawaiian shells as *C. carneola propinqua* Garrett, 1879. Burgess (1975) recognizes *C. propinqua* as a distinct species, distinguished by its smaller size, lack of purple on the sides, and mantle with studlike papillae.

Cypraea cernica Sowerby, 1870. Fig. 67 G, H. (Synonym: *Cypraea cernica marielae* C. N. Cate, 1960.) Length, 34 mm; diameter, 20 mm; height, 15 mm. *Shell:* rotundly ovate; right margin pitted; fawn spotted with white. *Sides:* left side rounded; right side margined and pitted. *Aperture:* wide, sinuous; teeth prominent and coarse, extending on to base. *Color:* fawn sprinkled with irregular white spots or reticulations; mantle line brown; sides white spotted with dark brown; base, teeth and interstices white.

C. cernica is a rare deep-water species, occurring at depths of 30 to 100 m.

This species occurs throughout the Indo-West Pacific.

Cypraea childreni Gray, 1825. Fig. 67 M, N. Length, 25 mm; diameter, 15 mm; height, 12 mm. *Shell:* ovate, inflated, thin; extremities beaked; with transverse ribs across the dorsum and base; cream-colored. *Sides:* right margined, left rounded. *Aperture:* narrow, sinuous; with five teeth extending across the base as extensions of the dorsal ribs. *Color:* (subfossil) cream.

C. childreni has been recorded only from subfossil and beachworn shells.

This species occurs throughout the Pacific Ocean, recorded from the Philippines, Formosa, Japan, Australia, and various islands in the central Pacific.

Cypraea chinensis Gmelin, 1791. Fig. 67 Q, R. (Synonym: *Cypraea cruenta* Gmelin, Ostergaard, 1928; *C. chinensis amiges* Melvill and Standen, C. N. Cate, 1962.) Length, 33 mm; diameter, 24 mm; height, 17 mm. *Shell:* broadly oval, margins callused; dorsum reticulated brown and white, margins cream with purple spots. *Sides:* margined, callused, and spreading. *Aperture:* wide, slightly sinuous; labial teeth large,

coarse, extending almost to the margin of the base, columellar teeth fine, short. *Color:* dorsum reticulated with orange-brown, sides cream-white with violet spots, base cream, interstices of teeth bright orange. *Animal:* mantle red with darker blotches and starlike white splashes; papillae conical, off-white.

Specimens of *C. chinensis* are rare in Hawaiian waters occurring at depths of 5 to 25 m. This species has been recorded in Pleistocene fossil deposits by Ostergaard (1928 as *C. cruenta).*

C. chinensis is a well-known species in the Indo-West Pacific. The deep-water habitat of *C. chinensis* in the Hawaiian Islands is to be contrasted with its shallow-water, reef habitat in Zanzibar, Mozambique, and the Philippines.

Cypraea cicercula Linnaeus, 1758. Fig. 67 C, D. (Synonym: *Cypraea cicercula tricornis* Jousseaume, Ostergaard, 1928; *C. circercula margarita* Schilder and Schilder, 1938.) Length, 20 mm; diameter, 22 mm; height, 11 mm. *Shell:* globular with beaked extremities; pustulate; cream-white sprinkled with small, brown dots; spire blotched. *Sides:* rounded. *Aperture:* narrow, barely sinuous; teeth fine, extending on to base. *Color:* cream-white sprinkled with small brown spots and with a prominent dorsal sulcus; base, teeth, and interstices white. *Animal:* foot lemon yellow.

C. cicercula is a rare species, recorded primarily from beachworn specimens; living animals have been collected at depths of from 6 to 10 m. Ostergaard (1928, 1939) reported this species from Pleistocene fossil deposits on Oahu and Molokai.

C. cicercula is distributed throughout the Indo-West Pacific.

Cypraea erosa Linnaeus, 1758. Fig. 67 U, V. (Synonym: *Cypraea erosa lactescens* Dautzenberg and Bouge, Schilder and Schilder, 1938.) Length, 30 mm; diameter, 19 mm; height, 14 mm. *Shell:* elongate-ovate, sides margined and pitted; gray-brown speckled with white, base blotched with brown. *Sides:* right side margined and deeply pitted. *Aperture:* wide, slightly curved; teeth large, labial teeth extending to the sides, columellar teeth extending halfway across the base. *Color:* dorsum fawn or gray-brown speckled with white and with a blue-gray dorsal line between the extremities; sides with brown ridges and a rectangular brown blotch in the center; base white spotted with orange-brown.

Although specimens of *C. erosa* are common in Pleistocene deposits on Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939), there are only two or three records of living animals found in Hawaiian Island waters in recent years.

C. erosa is a widely distributed species in the Indo-West Pacific.

Cypraea fimbriata Gmelin, 1791. Figs. 66 A, B, C; 67 E, F. (Synonyms: *Cypraea unifasciata* Mighels, 1845; *Palmadusta waikikiensis* Schilder, 1933.) Length, 12 mm; diameter, 5.5 mm; height, 4 mm. *Shell:* ovoid-elongate; margined; blue-gray freckled with brown. *Sides:* left rounded, right sharply margined. *Aperture:* wide, slightly sinuous, dilated anteriorly; teeth weak, labial teeth extending on to base, columellar teeth confined to aperture. *Color:* dorsum blue-gray with numerous pale brown freckles and a double brown band across the center; extremities tipped with purple. *Animal:* mantle and foot orange-red, the foot also with a few scattered white spots; mantle with sparse, simple, white papillae.

C. fimbriata is a common species both in shallow water and to depths of 80 m.

This species is distributed throughout the Indo-West Pacific.

Cypraea gaskoini Reeve, 1846. FRONTISPIECE. (Synonyms: *Cypraea esontropia* Duclos, Martens and Langkavel, 1871; *Cypraea peasei* Sowerby, Ostergaard, 1928.) Length, 15 mm; diameter, 11 mm; height, 9.5 mm. *Shell:* elongate to ovate; yellow-brown reticulated with milky white spots. *Sides:* lightly margined, with slightly raised spots. *Aperture:* wide, sinuous; base convex; teeth prominent, labial teeth extending on to base. *Color:* dorsum yellow-brown to rusty-red reticulated by numerous milky-white spots, mantle line prominent; sides white peppered with distinct chocolate or orange-brown spots; base white. *Animal:* mantle, proboscis, tentacles, and foot bright red; papillae simple, sparse.

C. gaskoini is rather uncommonly encountered but is not rare in Hawaiian waters, occurring at depths of from 1 to 30 m. It is recorded from Pleistocene fossil deposits on Oahu (Ostergaard, 1928 as *C. peasei*).

This species is endemic to the Hawaiian Islands.

Cypraea granulata Pease, 1863c. FRONTISPIECE. (Synonyms: *Cypraea madagascariensis* Martens and Langkavel, 1871; *Cypraea honoluluensis* Melvill, 1888.) Length, 24 mm; diameter, 16 mm; height, 9 mm. *Shell:* broadly oval, slightly depressed; sides spreading; dorsum with nodules joined by intervening ridges; creamy- or rose-brown. *Sides:* spreading, flattened. *Aperture:* narrow, slightly sinuous; teeth extending across the base as extensions of the dorsal ridges; base flat. *Sculpture:* dorsum covered with nodules joined by intervening ridges; ventral surface with transverse teeth. *Color:* rose-brown when first collected, fading to creamy-brown; base lighter; teeth outlined in red-brown. *Animal:* mantle gray-green mottled with cream; papillae numerous and dendritic.

These cowries occur at moderate depths of from 3 to 15 m. Ostergaard (1928, 1939) reported *C. granulata* (as *C. madgascariensis*) from Pleistocene fossil deposits on Oahu and Molokai.

This species is endemic to the Hawaiian Islands.

Cypraea helvola Linnaeus, 1758. Fig. 67 I, J. (Synonym: *Cypraea kauilani* Kenyon, 1900; *C. hawaiiensis* Melvill, 1888.) Length, 22 mm; diameter, 16 mm; height, 12 mm. *Shell:* ovate; sides margined and pitted; dorsum purple-red or gray-brown spotted with brown and white. *Sides:* right side margined and strongly pitted. *Aperture:* narrow, straight; teeth coarse, both labial and columellar teeth extending partially across the base. *Color:* (fades in collections) dorsum purple-red or gray-brown with small white spots and larger, superimposed brown spots; extremities pale lilac to deep purple; sides and base orange-brown. *Animal:* mantle mottled red-brown; papillae light yellow with red tips; tentacles and proboscis orange-red; foot dorsally red-brown with yellow spots.

A common species, *C. helvola* occurs both in shallow water and to depths of 40 m. It is more abundant in deeper waters than along the shoreline and apparently is the most common cowry at depths of more than 20 m. Ostergaard (1928, 1939) records this species from Pleistocene fossil deposits on Oahu and Molokai.

C. helvola is widely distributed throughout the Indo-West Pacific, to Clipperton Island.

Cypraea isabella Linnaeus, 1758. Figs. 66 D; 68 G, H. (Synonym: *Luria controversa* Gray, Schilder and Schilder, 1938.) Length, 32 mm; diameter, 19 mm;

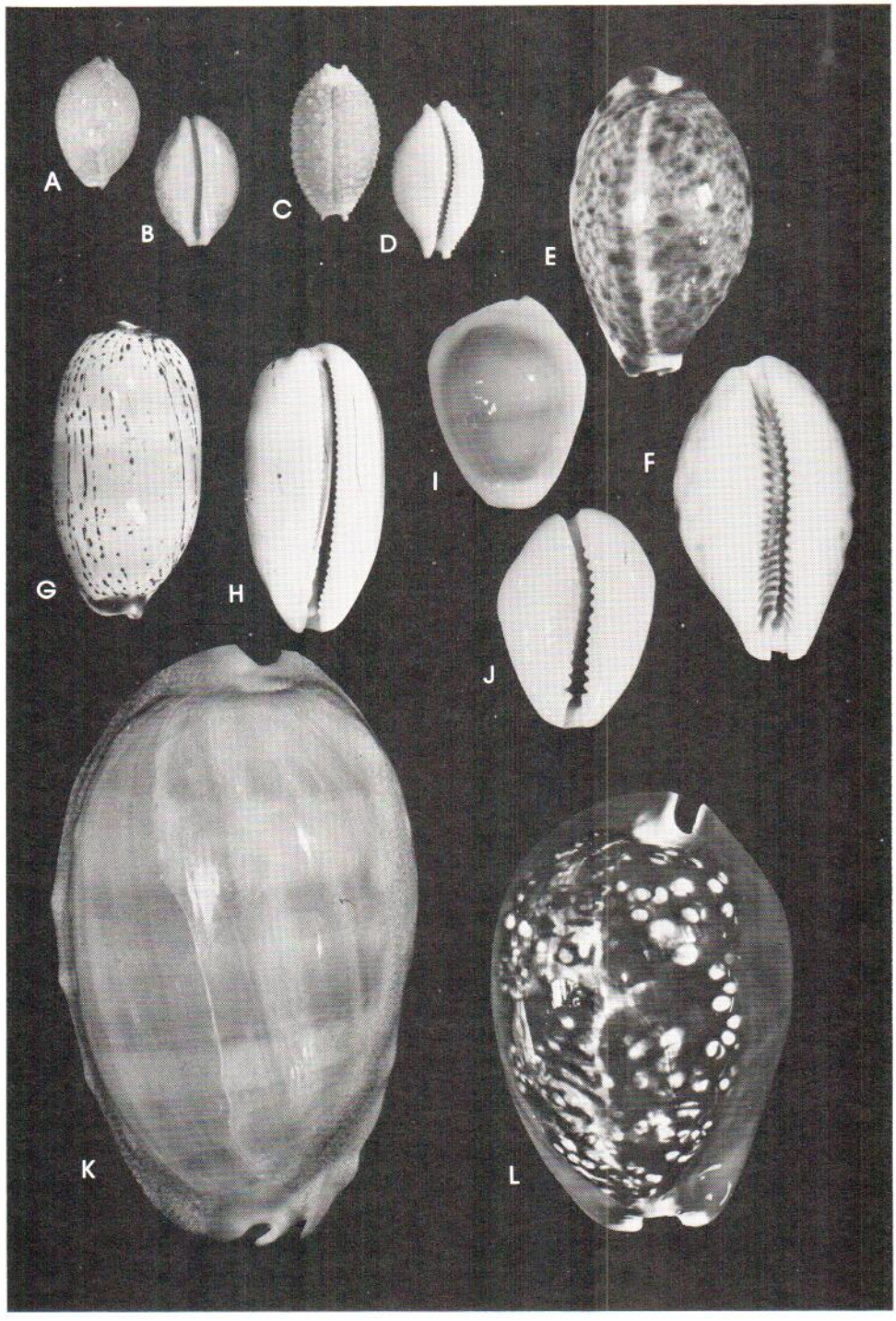


Figure 68.—**Cypraeidae.** A, B. *Cypraea mariae*, length 20 mm. C, D. *C. nucleus*, length 17 mm. E, F. *C. lynx*, length 40 mm. G, H. *C. isabella*, length 32 mm. I, J. *C. moneta*, length 26 mm. K. *C. leviathan*, length 70 mm. L. *C. mauritiana*, length 90 mm.

height, 15 mm. *Shell:* cylindrical; orange-brown with linear black streaks, extremities dark brown. *Aperture:* narrow, almost straight, teeth fine, numerous, confined to aperture. *Sides:* rounded. *Color:* dorsum orange-brown or fawn obscurely three-banded with darker tones and with scattered black flecks and lines; extremities brown tipped with orange; sides, base, and teeth white. *Animal:* mantle, proboscis, and tentacles velvet black; mantle texture smooth; foot light fawn.

A common shallow-water species, *C. isabella* also occurs at depths to 80 m. This species has been recognized in Pleistocene fossil deposits on Oahu and Molokai (Ostergaard, 1928, 1939).

C. isabella is a well-known and widely distributed species in the Indo-West Pacific.

Cypraea leviathan Schilder and Schilder, 1938. Fig. 68 K. Length, 70 mm; diameter, 44 mm; height, 35 mm. *Shell:* cylindrical; red-brown with darker bands on the dorsum; margins light tan freckled with white. *Sides:* sloping; base convex. *Aperture:* wide, sinuous; teeth strong, labial teeth extending partially onto base. *Color:* dorsum red-brown crossed by transverse darker bands; sides tan with minute white spots and striated vertically with hairlike lines; interstices of teeth purple. *Animal:* mantle red-brown mottled with gray and black; papillae sparse, palmate, yellow; proboscis and tentacles dark gray; foot gray to black.

A common species in Hawaiian waters, *C. leviathan* is found in shallow water under coral boulders and blocks near the edge of reefs and along the surf-beaten areas of basalt coastline to depths of 8 m.

C. leviathan is distributed at the periphery of the Indo-West Pacific, from Kenya (Schilder, 1962) to the Line Islands and Hawaii.

Cypraea lynx Linnaeus, 1758. Fig. 68 E, F. (Synonym: *Cypraea lynx caledonica* Crosse, Schilder and Schilder, 1939.) Length, 40 mm; diameter, 25 mm; height, 21 mm. *Shell:* ovate-cylindrical; cream spotted and clouded with dark brown, interstices of teeth orange. *Sides:* rounded or slightly callused. *Aperture:* narrow, slightly curved; teeth large, labial teeth extending partially across base; base flat. *Color:* dorsum blue-white to brown, spotted and clouded with fulvous brown interspersed with darker spots; sides, base, and teeth white; interstices of teeth orange.

This is a rare species in Hawaii and there are records of only four or five live-collected specimens of *C. lynx;* all were found in shallow water on reefs. This species is known from Pleistocene deposits on Oahu (Ostergaard, 1928).

C. lynx occurs throughout the Indo-West Pacific.

Cypraea maculifera Schilder, 1932. Fig. 69 J, K. (Synonym: *Cypraea reticulata* Martyn, Martens and Langkavel, 1871.) Length, 66 mm; diameter, 41 mm; height, 34 mm. *Shell:* oval, solid; margins flattened; reticulated brown and white; base flesh-tinted with a black blotch. *Sides:* angular and strong, slightly swollen. *Aperture:* wide, curved; teeth coarse, extending partially across the convex base. *Color:* dorsum brown reticulated with white and with a distinct mantle line; sides mottled with gray, base creamy or flesh-tinted, with a large, black blotch; teeth dark brown.

C. maculifera is a commonly occurring shallow-water species, and specimens are found in dark holes along rocky shorelines and to depths of about 16 m, usually where

there is considerable wave action. This species was recorded from Pleistocene fossil deposits on Oahu (Ostergaard, 1928 as *C. reticulata).*

C. maculifera is widely distributed in the Indo-West Pacific, from the Seychelles (Schilder, 1965) throughout the Pacific (Schilder and Schilder, 1939) to Clipperton Island (Hertlein and Allison, 1966).

Cypraea mariae Schilder, 1927. Fig. 68 A, B. (Synonym: *Cypraea annulata* Gray, Ingram, 1936.) Length, 20 mm; diameter, 14 mm; height, 13 mm. *Shell:* spherical; ivory-white with yellow spots ocellated with brown. *Sides:* rounded. *Aperture:* narrow, straight, posteriorly slightly angled; teeth numerous and fine, confined to aperture; base flat. *Color:* dorsum ivory-white sprinkled with brown rings ocellated with yellow; sides, base, and teeth white.

C. mariae is known only from beachworn and subfossil specimens in the Islands.

This species is distributed throughout the Pacific Ocean, from the Philippine Islands and Palaus to the Tuamotus.

Cypraea mauiensis Burgess, 1967. FRONTISPIECE. Length, 13 mm; diameter, 8 mm; height, 7 mm. *Shell:* spherical, extremities produced but blunt; dorsum with microscopic pustules; cream with three paired brown blotches on the dorsum. *Sides:* rounded, inflated. *Aperture:* narrow, slightly curved posteriorly; teeth fine, partially extending on to base. *Color:* dorsum tan to light yellow, with three paired brown dorsal blotches above the spire, medially and anteriorly. *Animal:* mantle yellow with gray spots; papillae tentacular and beaded.

This species is uncommon, found at depths of from 1 to 2 m, on the undersurfaces of the coral *Porites lobata* on Maui.

C. mauiensis was described from the Hawaiian Islands.

Cypraea mauritiana Linnaeus, 1758. Fig. 68 L. (Synonym: *Cypraea mauritiana calexquina* Melvill and Standen, Schilder and Schilder, 1939.) Length, 93 mm; diameter, 65 mm; height, 44 mm. *Shell:* oval, dorsum humped; sides spreading and angled; rich brown reticulated with white and with dark brown margins and base. *Sides:* margined, spreading, angled, and thick. *Aperture:* wide, sinuous; base convex; teeth large, coarse, extending partially across the base. *Color:* dorsum dark brown reticulated with white or cream; sides, base, and teeth dark brown. *Animal:* mantle black; papillae tentacular, dark brown; tentacles and proboscis orange-red; ventral surface of foot light brown.

A common shallow-water species, these cowries are found under ledges and in crevices of basalt outcrops and to depths of 2 m, usually where there is considerable wave action. This species has been recorded from Pleistocene fossil deposits on Oahu (Ostergaard, 1928).

C. mauritiana is distributed throughout the Indo-West Pacific.

Cypraea moneta Linnaeus, 1758. Fig. 68 I, J. (Synonym: *Cypraea moneta barthelmyi* (Bernardi) Schilder and Schilder, 1938.) Length, 26 mm; diameter, 21 mm; height, 11 mm. *Shell:* pyriform to triangular; sides thick and callused; pale yellow. *Sides:* thickened and angular, often noduled. *Aperture:* wide, dilated anteriorly,

slightly curved posteriorly; teeth coarse and short, extending partially across the base. *Color:* pale yellow or cream, often with narrow gray or black transverse bands. *Animal:* mantle cream-white veined with black; tentacles cream; proboscis buff; papillae simple and dendritic, cream.

This species is uncommon in Hawaiian waters, occasionally collected under loose rock in sandy mud or in tide pools. The money cowry seems to be more common on Maui and Hawaii than it is on the northern islands. *C. moneta* was recorded from Pleistocene fossil deposits on Molokai (Ostergaard, 1928).

C. moneta is widely distributed in the Indo-West Pacific and is found at Clipperton Island.

Cypraea nucleus Linnaeus, 1758. Fig. 68 C, D. (Synonym: *Cypraea nucleus gemmosa* Perry, C. N. Cate, 1965.) Length, 17 mm; diameter, 10 mm; height, 7.5 mm. *Shell:* ovate, extremities produced; with dorsal pustules and ridges; cream-colored. *Sides:* rounded. *Aperture:* narrow, barely sinuous; teeth extending across base, with shorter, intersticial teeth on the columellar lip. *Color:* cream to light yellow.

This species is rare in Hawaii, with living animals collected at depths of less than 1 m off Oahu (Kay and Weaver, 1963) and 7 m off Maui (Tiedeman, 1966).

C. nucleus is distributed throughout the Indo-West Pacific from East Africa to Hawaii. It is apparently fairly common in shallow water in the central Pacific.

Cypraea ostergaardi Dall, 1921. FRONTISPIECE. (Synonyms: *Cypraea pacifica* Ostergaard, 1920; *Cypraea alleni* Ostergaard, 1950.) Length, 18 mm; diameter, 13.5 mm; height, 8.5 mm. *Shell:* ovate, inflated; dorsum, sides and base cream, spotted with brown. *Sides:* slightly margined, pitted on the right. *Aperture:* narrow, straight; teeth small, delicate, barely extending on to base. *Color:* cream to rose-brown, sprinkled with chestnut brown spots; sides and base white.

This is a rare deep-water species, and most specimens recorded are either beachworn or subfossil; most of the shells have been dredged at depths of 20 to 40 m.

C. ostergaardi is endemic to the Hawaiian Islands.

Cypraea poraria Linnaeus, 1758. Fig. 67 K, L. (Synonyms: *Cypraea poraria* var. *kavaiensis* Melvill, 1888; *C. poraria scarabaeus* Bory, Schilder and Schilder, 1938.) Length, 19 mm; diameter, 13 mm; height, 9 mm. *Shell:* ovate; purple with brown spots ocellated with white. *Sides:* weakly margined, pitted. *Aperture:* narrow, straight; teeth extending partially across base. *Color:* dorsum purple with numerous brown spots ocellated with white; extremities, sides and base light purple. *Animal:* mantle splashed with purple similar to shell color; papillae conical and dendritic, cream-colored.

A fairly common species in the Hawaiian Islands, specimens are found in living and dead coral at depths of from 1 to 6 m.

C. poraria is distributed throughout the Indo-West Pacific.

Cypraea rashleighana Melvill, 1888. Fig. 69 A, B. (Synonym: *Cypraea latior,* Melvill, 1888.) Length, 29 mm; diameter, 14 mm; height, 12 mm. *Shell:* ovate,

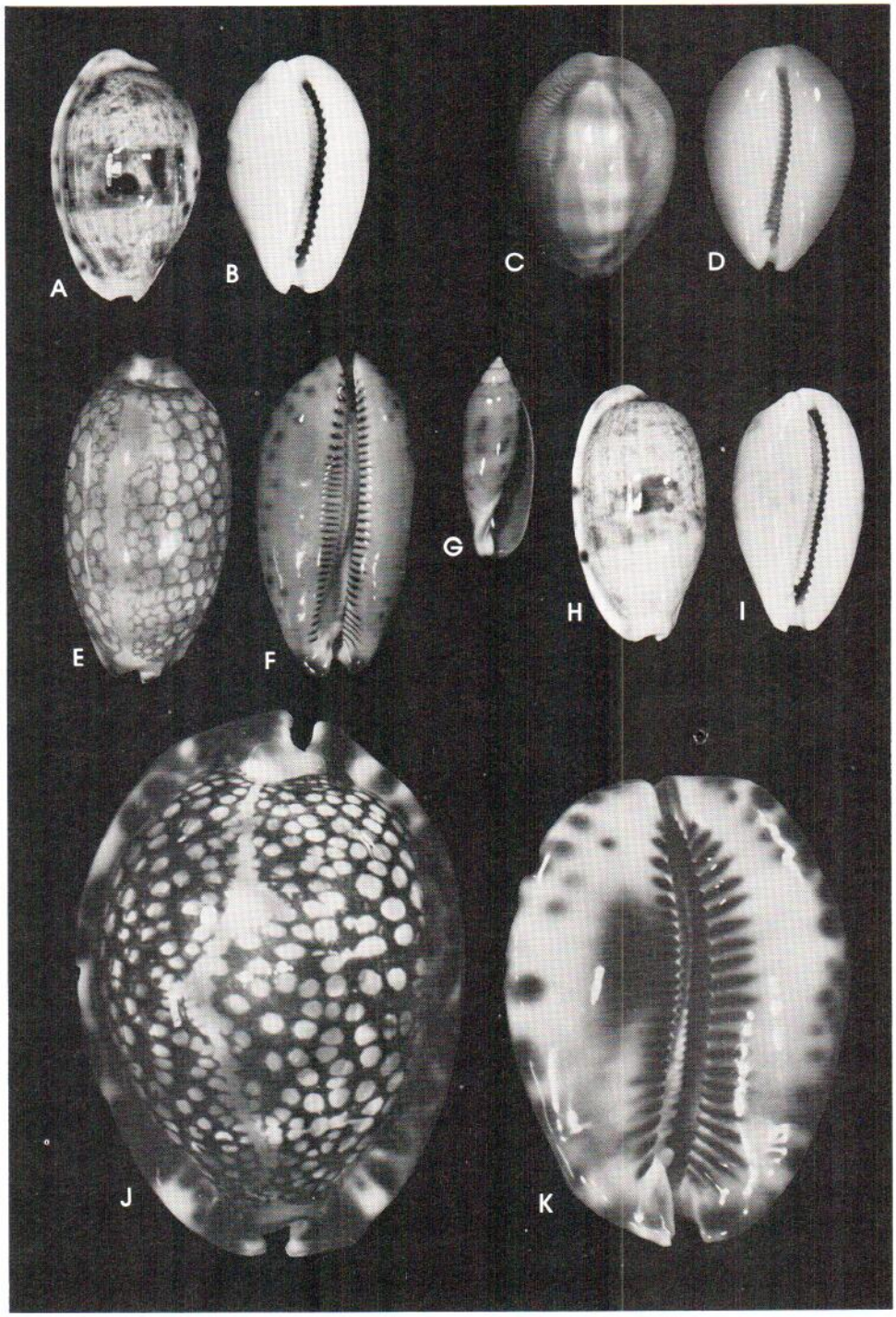


Figure 69.—**Cypraeidae.** A, B. *Cypraea rashleighana,* length 29 mm. C, D. *C. schilderorum,* length 34 mm. E, F, G. *C. scurra,* length of adult 43 mm; length of juvenile 20 mm. H, I. *C. teres,* length 25 mm. J, K. *C. maculifera,* length 66 mm.

inflated; gray-blue blotched with brown, margins white, spotted with brown. *Sides:* both margins pronounced and callused. *Aperture:* narrow, straight; teeth weak, confined to aperture. *Color:* dorsum pale cream tinted with blue, spotted, and blotched with brown, lateral spots extending over the white sides. *Animal:* mantle, proboscis, tentacles and foot orange-red; papillae as granular knobs.

These shells are rare in the windward islands, but more common at Midway. Live-collected animals are found at depths of 20 to 30 m.

C. rashleighana was described from the Loyalty Islands but no shells comparable with the type have been found except in the Hawaiian Islands (Burgess, pers. comm.), and at Cocos Island, Galapagos Islands (Emerson and Old, 1965). The locality cited by Melvill may have been an error.

Cypraea schilderorum (Iredale, 1939). Fig. 69 C, D. (Synonyms: *Cypraea ventriculus* Lamarck, Baldwin, 1898; *Cypraea arenosa* Gray, 1824, Ingram, 1936.) Length, 34 mm; diameter, 22 mm; height, 17 mm. *Shell:* broadly ovate, solid; orange-brown with four bands of darker brown; teeth fine. *Sides:* spreading, heavy. *Aperture:* narrow, slightly curved; teeth numerous, fine, confined to aperture. *Color:* dorsum red-brown, centrally lighter, with four darker bands; sides fawn mottled and striated with lighter tones; base and teeth white. *Animal:* mantle mottled black, brown, and white; papillae simple and dendritic, cream white; tentacles black; foot dorsally light tan, ventrally cream.

These animals occur in moderately deep water at depths of 4 to 10 m.

C. schilderorum occurs in the Pacific Ocean from Fiji to Polynesia and in Micronesia in the Marshall Islands, Tuamotus, Line Islands, Johnston Island, and Fiji (Cernohorsky, 1964a), and Clipperton Island.

Cypraea scurra Gmelin, 1791. Fig. 69 E-G. (Synonym: *Cypraea scurra retifer* Menke. Schilder and Schilder, 1939.) Length, 43 mm; diameter, 22 mm; height, 19 mm. *Shell:* cylindrical, narrow; blue-gray reticulated with brown and with blue-gray spots. *Sides:* rounded. *Aperture:* narrow, straight; teeth fine, short, barely extending on to base. *Color:* dorsum blue-gray reticulated with brown and with white or blue-gray spots; sides light brown with dark brown and black spots; base tan. *Animal:* mantle gray-brown with a deep orange band around the dorsal margin within the shell; foot dorsally green-brown, ventrally pale brown; papillae leaflike.

Uncommon in the Hawaiian Islands, *C. scurra* appears to be associated with the coral *Porites lobata*, and is found at depths of 3 to 8 m. This species is recorded in Pleistocene fossil deposits on Oahu (Ostergaard, 1928).

C. scurra is distributed through the Indo-West Pacific to Clipperton Island.

Cypraea semiplota Mighels, 1845. FRONTISPIECE. (Synonyms: *Cypraea spadix* Mighels, 1845; *C. polita* Roberts, 1868; *C. annae* Roberts, 1869.) Length, 16 mm; diameter, 9 mm. *Shell:* elongate to ovate; extremities and right margin pitted; fawn with minute white spots. *Sides:* right margin ridged and pitted. *Aperture:* narrow, moderately curved; teeth small, columellar teeth partially extending across base, labial teeth extending across base. *Color:* dorsum fawn, freckled with minute white spots; extremities darker orange-brown; base white; teeth white, interstices red-orange. *Mantle:* black with minute white papillae.

C. semiplota was rather commonly collected in shallow water until about 1940, but between 1940 and 1970 only occasional living animals were found. Since 1970 shells have become more common. The shells are variable in shape.

This species is endemic to the Hawaiian Islands.

Cypraea sulcidentata Gray, 1824. FRONTISPIECE. Length, 35 mm; diameter, 26 mm; height, 21 mm. *Shell:* oval, inflated; creamy brown banded by four darker bands. *Sides:* rounded, barely thickened. *Aperture:* narrow, curved; teeth coarse, deeply incised, extending partially across the base. *Color:* dorsum fawn with four bands of darker brown across the middle; sides marbled with creamy brown; base and teeth white. *Animal:* mantle mottled black, brown and white; papillae dendritic, cream-white; tentacles black; foot dorsally light tan, ventrally cream.

C. sulcidentata occurs in moderately deep water and is fairly common at depths of 2 to 24 m; the animals are usually found in coral heads.

C. sulcidentata is endemic to the Hawaiian Islands.

Cypraea talpa Linnaeus, 1758. Fig. 70 B. (Synonym: *Cypraea talpa saturata* Dautzenberg, Schilder and Schilder, 1938.) Length, 72 mm; diameter, 38 mm; height, 33 mm. *Shell:* cylindrical, bulbous; dorsum fawn, base and margins dark brown. *Sides:* rounded. *Aperture:* narrow; teeth fine and short, confined to the aperture. *Color:* dorsum fawn banded with darker or lighter sides and base chocolate brown. *Animal:* papillae leaflike; mantle dark brown or black, the animals with black mantles having rectangles of fluorescent green outlined in black; foot, proboscis, and tentacles black.

Rather uncommon, *C. talpa* occurs at depths of 1 to 20 m, usually in coral heads. Ostergaard (1928) reported the species from Pleistocene deposits on Oahu.

C. talpa is distributed throughout the Indo-West Pacific. It apparently has a shallow-water habitat elsewhere in its range (Steadman and Cotton, 1943; Bayer and Neurohr, 1946; Ingram, 1939b).

Cypraea teres Gmelin, 1791. Fig. 69 H, I. (Synonyms: *Cypraea tabescens,* Melvill, 1888; *C. teres pellucens* Schilder and Schilder, 1938; *C. punctulata* Ostergaard, 1939.) Length, 25 mm; diameter, 15 mm; height, 12 mm. *Shell:* cylindrical; right margin more prominent than left; blue flecked and blotched with brown. *Sides:* right side margined; left side rounded. *Aperture:* narrow, curved; labial teeth coarse and extending partially across the base; columellar teeth fine, confined to aperture. *Color:* dorsum gray-green to blue with irregular brown flecks and blotches, the largest an irregular blotch in the center; sides white spotted with brown; base, teeth, and interstices white. *Animal:* mantle red or red-orange spotted with darker; papillae rounded knobs; siphon spotted with white.

C. teres is a common species in shallow water and to depths of about 3 m. This species was recorded from Pleistocene fossil deposits on Molokai (Ostergaard, 1939 as *C. punctulata).* The cowry amputates the posterior part of its foot when it is disturbed.

C. teres is distributed throughout the Indo-West Pacific and is also found at Clipperton Island.

Cypraea tessellata Swainson, 1822. FRONTISPIECE. Length, 38 mm; diameter, 27 mm; height, 22 mm. *Shell:* pyriform, inflated; orange-brown with darker bands and

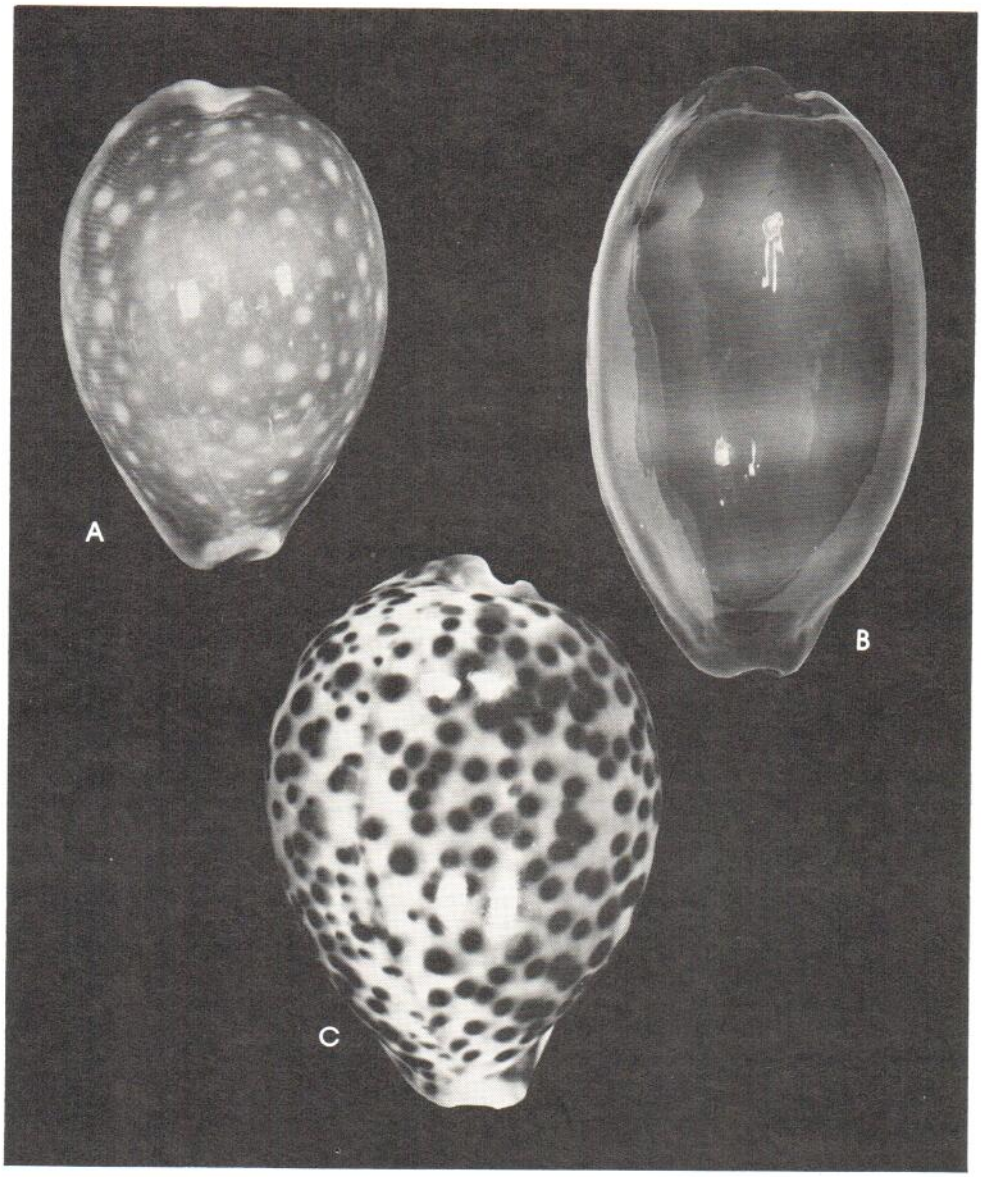


Figure 70.—**Cypraeidae.** A. *Cypraea vitellus,* length 50 mm. B. *C. talpa,* length 72 mm. C. *C. tigris,* length 117 mm.

with a pair of large dark brown spots on each side. *Sides:* slightly thickened, rounded. *Aperture:* narrow, straight; teeth fine and numerous, barely extending on to base. *Color:* dorsum creamy-brown crossed by three darker brown bands; sides white with a pair of square orange-brown spots and toward the base with irregular white and orange-brown spots; base brown and white; teeth tinted orange. *Animal:* mantle and foot yellow-gray, almost transparent, lacking papillae; proboscis yellow; tentacles and ventral surface of foot white.

C. tessellata occurs most commonly in moderately deep water at depths of 8 to 20 m, but specimens have been found in water less than a meter in depth and dredged from 100 m. This species has been recorded from Pleistocene fossil deposits on Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939).

C. tessellata is endemic to the Hawaiian Islands, but is also found at Johnston Island.

Cypraea tigris Linnaeus, 1758. Fig. 70 C. (Synonym: *Cypraea tigris lyncichroa* Melvill, Schilder and Schilder, 1939; *C. tigris schilderiana* C. N. Cate, 1961.) Length, 117 mm; diameter, 80 mm; height, 64 mm. *Shell:* globose, inflated; white spotted with black. *Sides:* rounded. *Aperture:* wide, sinuous; teeth coarse, barely extending on to the base. *Color:* dorsum white spotted or mottled with dark brown or black; sides, base, and teeth white. *Animal:* mantle, proboscis, tentacles, and foot dark gray; papillae elongate, simple, gray-yellow with creamy tips.

This is a common species in Hawaiian waters at depths of from 4 to 40 m.

C. tigris is a well known species throughout the Indo-West Pacific. It apparently reaches its greatest size in the islands which form the northeastern periphery of its range, and it is on the basis of size that C. N. Cate (1961) recognizes the Hawaiian subspecies as *C. t. schilderiana*. The deep-water habitat of Hawaiian tiger cowries is to be contrasted with their reef and shallow-water habits elsewhere in their range.

Cypraea vitellus Linnaeus, 1758. Fig. 70 A. (Synonym: *Cypraea vitellus polynesiae,* Schilder and Schilder, 1939.) Length, 50 mm; diameter, 31 mm; height, 26 mm. *Shell:* pyriform, inflated; fawn sprinkled with white spots. *Sides:* rounded. *Aperture:* wide, curved; teeth coarse, labial teeth extending partially on to the base. *Color:* dorsum fawn or brown profusely sprinkled with white spots of various sizes; sides gray-brown striated vertically with fine, hairlike lines; base, teeth, and interstices white. *Animal:* mantle cream splashed with gray and black; papillae sparse, simple, bi- and trifurcate, white; tentacles and proboscis gray; siphon cream.

Specimens of *C. vitellus* were apparently commonly collected in shallow water at depths of 1 m some twenty years ago, but are rarely seen now. Ostergaard (1928) records this species from Pleistocene fossil deposits on Oahu.

This species is widely distributed in the Indo-West Pacific, and to Clipperton Island.

Additional Records

Single specimens of *Cypraea arabica* Linnaeus, 1758, from Hawaii (Beck, 1962); *C. eglantina* Duclos, 1833, *C. gracilis* Gaskoin, 1849, and *C. staphylaea* Linnaeus, 1758 have also been recorded from the Hawaiian Islands. Two worn shells of *C. labrolineata* Gaskoin, 1849, were dredged off Waikiki at depths of 600 m (Burgess, 1964), one specimen has been live-collected (Weaver, 1965b), and a fossil shell is reported (Kosuge, 1969).

A fossil specimen of *Cypraea errones* was reported from Kahe Point, Oahu (Fair, 1973b).

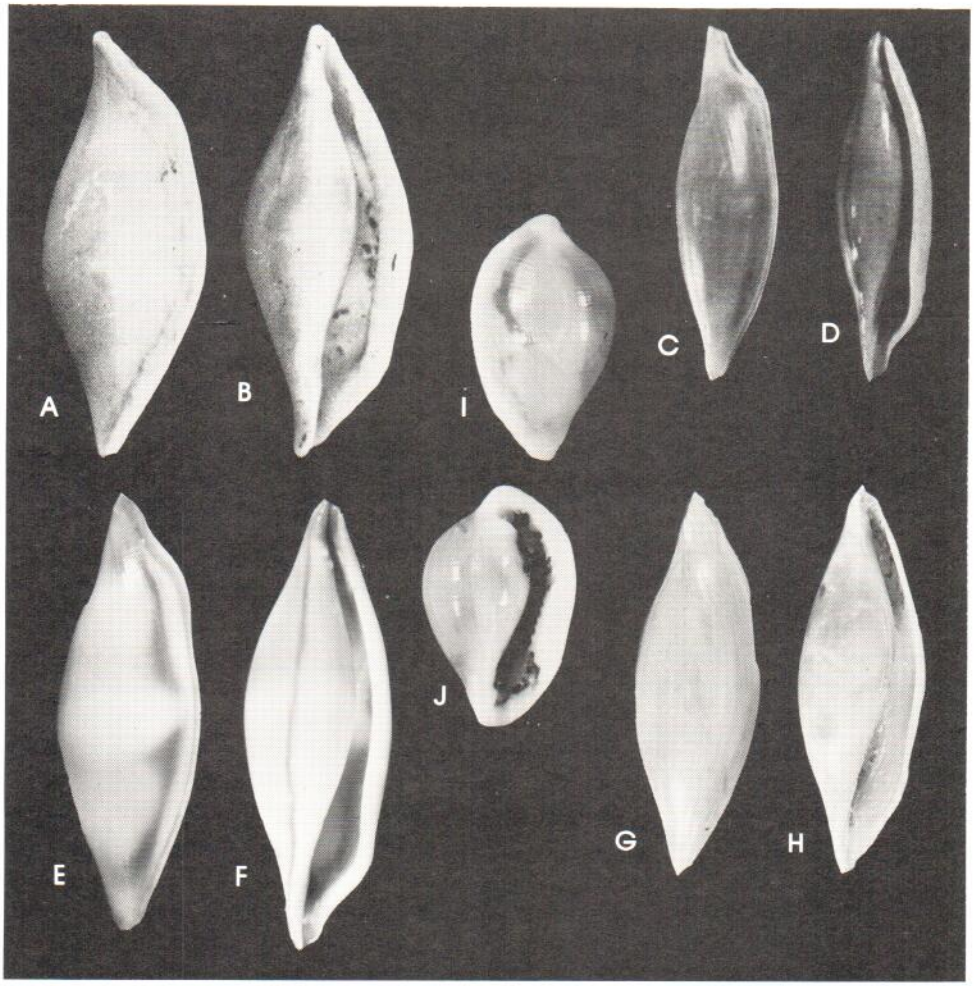


Figure 71.—**Ovulidae.** A, B. *Phenacovolva brevirostris*, length 29 mm. C, D. *P. lahainaensis*, length 30 mm. E, F. *P. weaveri*, length 22 mm. G, H. *Spiculata michaelkingi*, length 22 mm. I, J. *Margovula* sp. cf. *schilderorum*, length 12 mm.

Family **Ovulidae**

(**Amphiperatidae**)

Ovulid shells differ from those of the cowries by their involute form and lack of color patterns. There are also anatomical differences which distinguish ovulids and cypraeids, notably a long pedal nerve cord in the ovulids. Ovulids are carnivorous, feeding on stony or reef corals and gorgonaceans. The three species found in Hawaii all occur at depths of more than 50 m, where they are associated with gorgonaceans.

Margovula sp. cf. *schilderorum* C. N. Cate, 1973. Fig. 71 I, J. Length, 12 mm; diameter, 6 mm. *Shell:* ovate, broad posteriorly, narrow anteriorly, humped and with

produced terminals; microscopically transversely striate; gray-white. *Aperture:* wide, almost straight; outer lip thick, broad, rounded and with about 23 well-developed teeth. *Sculpture:* microscopic transverse striae. *Color:* glossy, gray-white.

These shells are rare, found with gorgonaceans or "precious" corals at depths of 600 m.

M. schilderorum was described from Foochow, China. The Hawaiian shells resemble Cate's description of the type in shape and size but lack the golden band on the right marginal sulcus.

Phenacovolva brevirostris (Schumacher, 1817). Fig. 71 A, B. Length, 29 mm; diameter, 11 mm. *Shell:* elongate-oval, narrowing toward the beaks; shoulders angled; beige-gray. *Aperture:* narrow, widening anteriorly. *Sculpture:* microscopic growth striae only. *Color:* beige-gray.

These gastropods are found with gorgonacean or "precious" corals, at depths of more than 50 m.

P. brevirostris occurs throughout the Pacific and is known from the Celebes-Sulu Sea, east Asian coast, Philippines, Taiwan, Japan, and the Cook Islands (C. N. Cate, 1969). The shells are distinguished from those of *P. lahainaensis* by their shorter, wider form.

Phenacovolva lahainaensis (C. N. Cate, 1969). Fig. 71 C, D. Length, 30 mm; diameter, 9 mm. *Shell:* narrow, elongate-ovate, subcylindrical; last whorl inflated; with faint parallel striae; translucent orange. *Aperture:* narrow posteriorly, widening anteriorly; left margin rounded, not thickened; outer lip thickened with a distinct carina extending the length of the outer lip; fossula subconcave; columella smooth, glossy; first funiculum bifid. *Sculpture:* transversely sculptured with faint, parallel, embossed zigzag lines. *Color:* translucent orange with a deep, rich orange line encircling the shell at the margins.

These shells are found at depths of 63 m associated with black coral.

P. lahainaensis was described from the Hawaiian Islands.

Phenacovolva weaveri C. N. Cate, 1973. Fig. 71 E, F. Length, 22 mm; diameter, 7 mm. *Shell:* elongate-ovate, narrowing toward the beaks; smooth and glossy; orange transversely banded with lighter color. *Aperture:* narrow, nearly straight, becoming broadly open anteriorly; outer lip edge roundly thickened, shouldered above. *Color:* orange-beige over pale gray with a wide transverse band of lighter color over the dorsum, a narrow lateral band of orange brown on the right side, and a bright orange line encircling the shell.

These ovulids are dredged at depths of 67 m.

P. weaveri was described from the Hawaiian Islands.

Spiculata michaelkingi C. N. Cate, 1973. Fig. 71 G, H. Length, 22 mm; diameter, 7 mm. *Shell:* fusiform, inflated; narrowing toward the beaks; smooth and glossy; orange. *Aperture:* broad, evenly curving; canals short, open at both ends; outer lip thin, thickened on the edge by a nacreous cord. *Color:* orange, dorsum pale gray-brown.

These ovulids are dredged at depths of more than 50 m.

S. michaelkingi was described from the Hawaiian Islands.

Superfamily ATLANTACEA

The Atlantacea is composed of three families of prosobranchs, the Atlantidae, Carinariidae, and Pterotracheidae, which are remarkably adapted to an active, predatory, pelagic existence on the high seas. Among their adaptations are the reduction of the visceral mass and shell; the inflation of the head-foot as a swollen gelatinous mass which gives them buoyancy; and the development of the sense organs, especially the eyes, which in *Carinaria* are long, tubular structures almost as long as the animal itself. Atlantaceans prey on fish and worms. The sexes are separate, fertilization is internal, and there is a veliger larva. In Hawaii, veligers of members of the Atlantidae are six-lobed (J. B. Taylor, 1975).

Among the three families there is a progressive reduction of the shell. In the Atlantidae (Fig. 55 E, F) it is compressed and planorboid, about 5 mm in diameter; it is apparently kept upright in swimming by the sharp keel on the periphery. In the Carinariidae the shell is caplike, a few millimeters in height, and it sits below the long animal which may reach a length of more than 10 cm. There is no shell in the Pterotracheidae, the animals being elongate and gelatinous.

Because of their pelagic habit, atlantaceans are widely distributed in the tropics. The shells are rarely seen on beaches, but shells of *Atlanta* spp. may be abundant in sediments at depths of more than 100 m.

Superfamily NATICACEA

Family **Naticidae**

The naticids have globular, smooth, polished shells which are white or decorated with spots or bands in shades of brown or black. The aperture is wide, ovate to semiovate, and the umbilicus may be deep or narrowed by callus.

These mollusks are generalized mesogastropods which have a number of adaptations associated with their mode of life in sand. The foot is large and fleshy, and often cannot be contained within the shell. The snails plough along beneath the surface of the sand, leaving a broad trail behind them. The anterior portion of the foot is enlarged, rising over the animal's head and effectively closing off the mantle cavity during burrowing. The eyes are reduced, lying within the epidermis. The egg masses consist of sand collars in which are embedded the egg capsules (Fig. 82 B).

Naticids are predators, feeding on other mollusks into which they bore, perhaps by means of an acid or enzymatic secretion produced by a small gland at the tip of the proboscis.

The supraspecific classification of the naticids is unsatisfactory, with the type of operculum and the arrangement of the callus pad used in the separation of genera and subgenera. Two genera are recognized here, *Natica* with a calcareous operculum and a funicle, a riblike structure of callus within the umbilicus; and *Polinices* with a chitinous operculum and the callus partially or completely closing the aperture. Nine species of naticids are recorded in Hawaiian waters to depths of 100 m, and two additional species have been described from depths of about 100 m. By way of

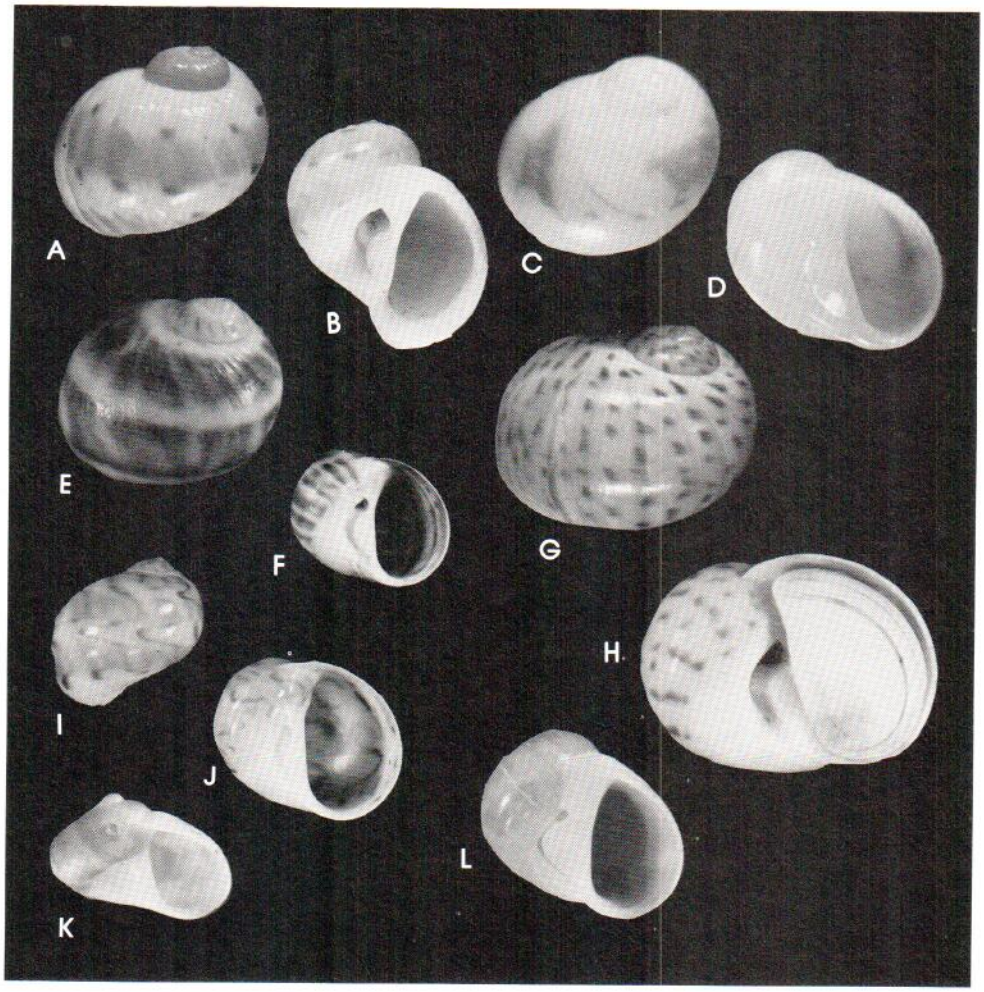


Figure 72.—**Naticidae.** A, B. *Natica alapapilionis*, height 15.5 mm. C, D. *N. bougei*, height 7 mm. E, F. *N. gualteriana*, height 25 mm. G, H. *N. hilaris*, height 14 mm. I, J. *Natica* sp., height 10 mm. K. *Eunaticina margaritaeformis*, height 3 mm. L. *Euspira sandwichensis*, height 15 mm.

contrast, 21 species are known from relatively shallow waters in Fiji (Cernohorsky, 1971b).

Eunaticina margaritaeformis Dall, 1924. Fig. 72 K. Height, 3 mm; diameter, 5 mm. *Shell:* globular-depressed; with spiral grooves; white banded with brown. *Spire:* protoconch of one and one-half smooth whorls, the apical whorl dark brown; last whorl of teleoconch the largest; suture deep. *Sculpture:* spiral sculpture of sharply incised spiral lines with much wider interspaces; axial sculpture of axial growth striae most conspicuous near the umbilicus. *Aperture:* obovate, oblique; umbilicus wide, circular, deep, extending to the apex; columella straight with a small callosity on its edge near the last whorl. *Color:* penultimate whorl brown, last whorl white with axial bands of brown.

These naticids are uncommon, found at depths of from 30 to 100 m.

E. margaritaeformis was described from the Hawaiian Islands.

Euspira sandwichensis (Dall, 1895). Fig. 72 L. Height, 16 mm; diameter, 15 mm. *Shell:* globose; thin and smooth; callus nearly filling a deep umbilicus; white. *Spire:* teleoconch of about five inflated whorls; suture appressed with a faint spiral groove in front. *Sculpture:* surface polished, with faint spiral markings and microscopic growth striae which are elevated as sharp, oblique wrinkles at the suture. *Aperture:* subovate; callus nearly filling a narrow, deep umbilicus. *Color:* white; periostracum thin, straw-colored.

These naticids are common at depths of about 400 to 500 m.

E. sandwichensis was described from the Hawaiian Islands.

Natica alapapilionis (Röding, 1798). Fig. 72 A, B. Height, 13.5 mm; diameter, 12.5 mm. *Shell:* globose; smooth and glossy; deeply but narrowly umbilicate; fawn spirally banded with spots of dark brown and white. *Spire:* protoconch of about two projecting whorls; teleoconch of about four whorls; suture distinct. *Sculpture:* smooth except for occasional wrinkles near the suture. *Aperture:* semiovate, wide; umbilicus open and extending anteriorly, the funicle entering rather obliquely; parietal callus mostly at the juncture of the last whorl. *Color:* fawn with three or four spiral bands of dark brown and white spots.

These naticids are rare, found at depths of 180 m.

N. alapapilionis is known from the Indian Ocean, Philippines, and Fiji (Cernohorsky, 1971b).

Natica bougei Sowerby, 1908a. Fig. 72 C, D. Height, 7 mm; diameter, 4.5 mm. *Shell:* pyriform-ovate; smooth; white with black-brown zigzag lines. *Spire:* four and one-half whorls, the last whorl the largest; suture distinct. *Sculpture:* smooth except for a few wrinkles below the suture. *Aperture:* semiovate; parietal callus filling the umbilicus, concave anteriorly; umbilicus represented by a shallow groove bordering the callus; operculum white, smooth, calcareous. *Color:* white, with irregular wavy, brown-black lines on the last whorl.

These shells are rare, dredged at depths of 12 to 16 m.

N. bougei was described from New Caledonia and is also known from Fiji (Cernohorsky, 1971b).

Natica gualteriana Recluz, 1844. Figs. 72 E, F; 82 B. (Synonyms: *Natica lurida* Philippi, 1852; *N. marochiensis* Gmelin, Bryan, 1915; *N. sagittata* Menke, Tinker, 1958.) Height, 27 mm; diameter, 25 mm. *Shell:* globular, solid; umbilicus deep and wide, filled with a large callosity; white, spirally banded with fawn or brown. *Spire:* distinct, of two or three whorls, the last whorl expanding and the largest; suture appressed. *Sculpture:* smooth and polished, with sutural wrinkles. *Aperture:* semiovate; umbilicus deep and with a broad funicle; operculum calcareous, white, with a raised margin and a single sulcus within, a short groove surrounding the central part of the outside which has about two whorls. *Color:* variable — usually spirally banded with fawn or brown, base white and with a white spiral in front of the suture. *Animal:* exposed parts white, densely and minutely spotted with red.

This is the most commonly occurring of the Hawaiian naticids, found buried in sandy areas in shallow waters in tide pools, on reef flats, and to depths of 100 m. The egg masses consist of sand collars about 20 mm in diameter, each egg ribbon about 6 mm in diameter. The four-lobed veligers emerge from the egg collar when they are about 120 μm in diameter, grow to 900 to 1100 μm in diameter in the plankton, and metamorphose when three and one-quarter to three and one-half whorls are complete (J. B. Taylor, 1975). In the laboratory juveniles feed on small rissoaceans within 24 hours after metamorphosis, then, when they are about 2 mm in diameter, shift their feeding habits to *Bittium parcum*. In nature these naticids appear to feed principally on the bivalve *Ctena bella*. The first functional egg collars are deposited twelve weeks after metamorphosis (J. B. Taylor, 1975).

N. gualteriana is found in Pleistocene fossil deposits on Molokai (Ostergaard, 1939, as *N. marochiensis)*.

This is a common and well-known species in the Indo-West Pacific, but it has a confused taxonomic history. Hedley (1913) questioned the long-used name *N. marochiensis* for shells from Queensland, Australia, and utilized the Recluz name; Cernohorsky (1971b) also utilizes the Recluz name and restricts *N. marochiensis* to a Caribbean species.

Natica hilaris Sowerby, 1914. Fig. 72 G, H. Height, 14 mm; diameter, 16 mm; *Shell:* globose, shining; cream with spirals of chestnut spots. *Spire:* five or six whorls, the apical whorls barely convex, the last much the largest; suture appressed. *Sculpture:* smooth and shining except for wrinkles below the suture on the last whorls. *Aperture:* semicircular; parietal callus fairly prominent; umbilicus deep; funicle with a convex edge; operculum calcareous, white. *Color:* cream or ivory with five or six spirals of chestnut spots on the last whorl.

About a dozen specimens of *N. hilaris* have been found, dredged at depths of 80 to 200 m.

This species was described from Kii, Japan.

Natica sp. Fig. 72 I, J. (Synonym: *Natica sagittifera* Recluz, Tinker, 1952.) Height, 10 mm; diameter, 9.5 mm. *Shell:* globose; smooth and glossy; fawn gray with brown zigzag marks. *Spire:* four and one-half whorls, the last the largest; suture distinct. *Sculpture:* smooth except for a few wrinkles below the suture. *Aperture:* ovate; parietal callus nearly filling the umbilicus; umbilicus a shallow groove bordering the callus; operculum white, smooth except for a columellar ridge. *Color:* fawn gray with axial streaks of brown zigzag marks which occasionally may form spiral bands.

These shells are common at depths of 20 to 160 m.

These shells have been referred to *N. sagittifera* Recluz, 1852 (see Tinker, 1952) but are distinct, and are being described as a new species by Rehder (In press).

Polinices melanostomus (Gmelin, 1791). Fig. 73 A-D. (Synonym: *Polinices opacus* Recluz, Tinker, 1958.) Height, 18 mm; diameter, 14 mm. *Shell:* pyriform-ovate; solid; white or cream with brown banding or spots, columella dark brown. *Spire:* short; suture appressed. *Sculpture:* growth lines and occasional obsolete spiral striae. *Aperture:* semiovate; columella concave; parietal callus folded over umbilicus but not covering it. *Color:* cream to white, with three brown bands on the last whorl,

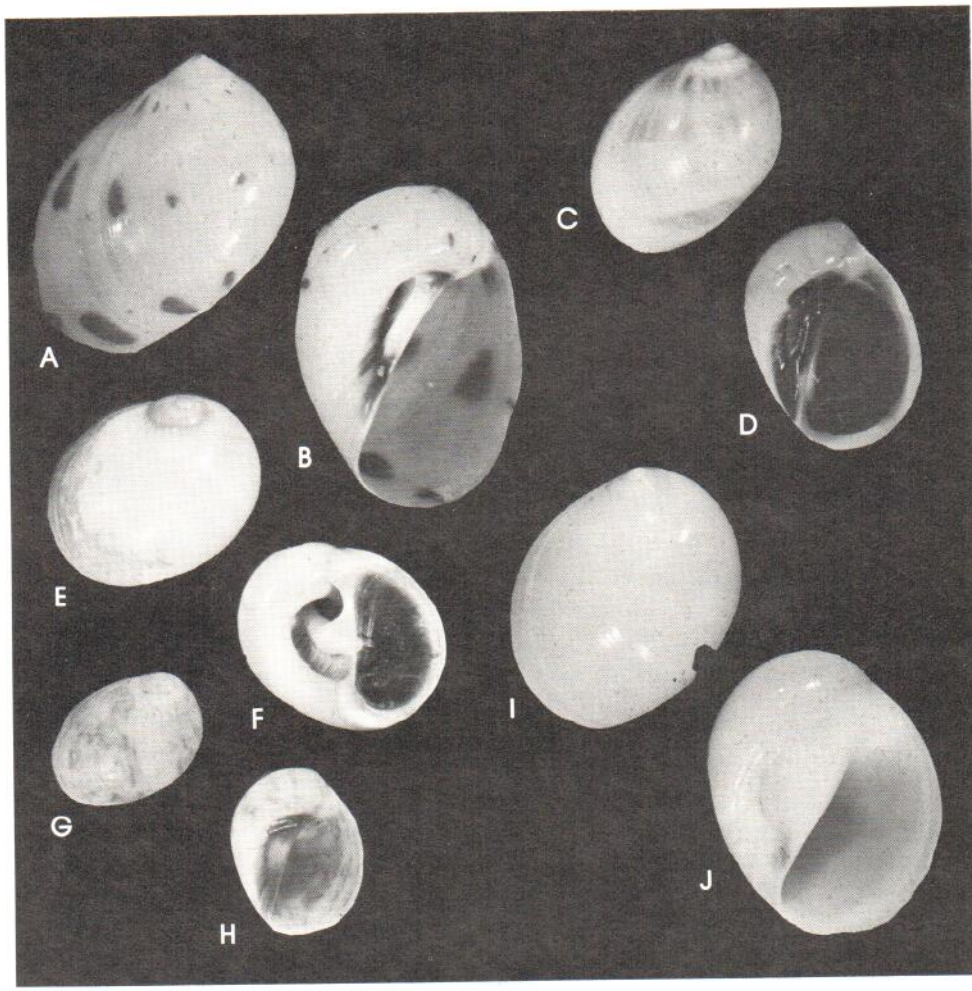


Figure 73.—**Naticidae.** A - D. *Polinices melanostomus*, two color forms. A, B. height 48 mm. C, D. height 30 mm. E, F. *P. peselephanti*, height 18 mm. G, H. *P. simiae*, height 25 mm. I, J. *P. tumidus*, height 25 mm.

occasionally with bands of brown spots, columella extensively stained with dark brown.

These naticids are rare at depths of 10 m.

P. melanostomus was described from "Indian Seas." Cernohorsky (1971b) reports these naticids as moderately common in Fiji.

Polinices peselephanti (Link, 1807). Fig. 73 E, F. Height, 18 mm; diameter, 25 mm. *Shell:* globose, solid; polished; deeply umbilicate, funicle columnar; white. *Spire:* low, of four whorls, the last whorl the largest. *Sculpture:* smooth except for microscopic growth striae and wrinkles below the suture. *Aperture:* semiovate; columella straight; umbilicus deep; funicle wide and columnar. *Color:* white or cream.

Specimens of *P. peselephanti* are found at depths of 40 to 160 m.

This species is known from Queensland, Australia, the Philippines, and southern Japan.

Polinices simiae (Deshayes in Deshayes and Edwards, 1838). Fig. 73 G, H. (Synonym: *Polinices opacus* Recluz, Tinker, 1958.) Height, 25 mm; diameter, 21 mm. *Shell:* globose; light and thin, shining; cream banded with brown, umbilicus and columella black. *Spire:* projecting, of four whorls, the last whorl the largest; suture appressed. *Sculpture:* with microscopic spiral threads and fine growth striae. *Aperture:* wide, semiovate; umbilicus open, parietal callus thin; operculum thin, corneous, pliable, dark red-brown or black. *Color:* white or cream, streaked or banded with brown; umbilicus and columella black.

Shells are common in beach drift. Living animals are rarely seen in shallow water, but have been dredged at depths of 80 m.

This species has been recorded from various localities in the Pacific including the Kermadec Islands (Cernohorsky, 1971b).

Polinices tumidus (Swainson, 1840). Fig. 73 I, J. (Synonym: *Polinices pyriformis* Recluz, Edmondson, 1933; *Natica mammila* [*sic*] Linnaeus, Tinker, 1952; *Natica opacus* Recluz, Morris, 1952.) Height, 33 mm; diameter, 29 mm. *Shell:* globose, oval, somewhat flattened; umbilicus covered by a thick, heavy callus pad; white. *Spire:* five whorls, the last whorl much the largest; suture appressed. *Sculpture:* smooth and polished, with growth striae only. *Aperture:* semiovate, the columella slightly sinuous; umbilicus covered by a large callus pad; operculum horny, light yellow or orange-brown. *Color:* white, apical whorl a minute brown spot.

Specimens of *P. tumidus* are occasionally found in shallow water buried in sand, but are more common at depths of 20 to 80 m. The animal is white and extremely large for the size of the shell. The shells are variable in size, some reaching lengths of nearly 50 mm. Juvenile shells may have a shallow umbilicus.

This naticid is widely distributed in the tropical Pacific. In Fiji it is found on sandbars and beaches at the high-tide level (Cernohorsky, 1971b). As with *Natica gualteriana*, this species has a confused taxonomic history, and several authors have incorrectly referred it to *Nerita mamilla* Linnaeus, 1758. Hedley (1924), however, suggests the Linnaean shell should be interpreted as a Caribbean species and considers *Natica pyriformis* Recluz, 1843, the correct name. Cernohorsky (1971b) suggests Swainson's *Mamillaria tumida* is the earliest applicable name for this species.

Superfamily TONNACEA

This superfamily includes five families, the Cassididae, Cymatiidae, Bursidae, Tonnidae, and Ficidae (= Pirulidae); all except the Ficidae are represented in Hawaiian waters. The group includes not only some of the largest of the mesogastropods, but also some of the most specialized, for the members of the Tonnacea are carnivorous.

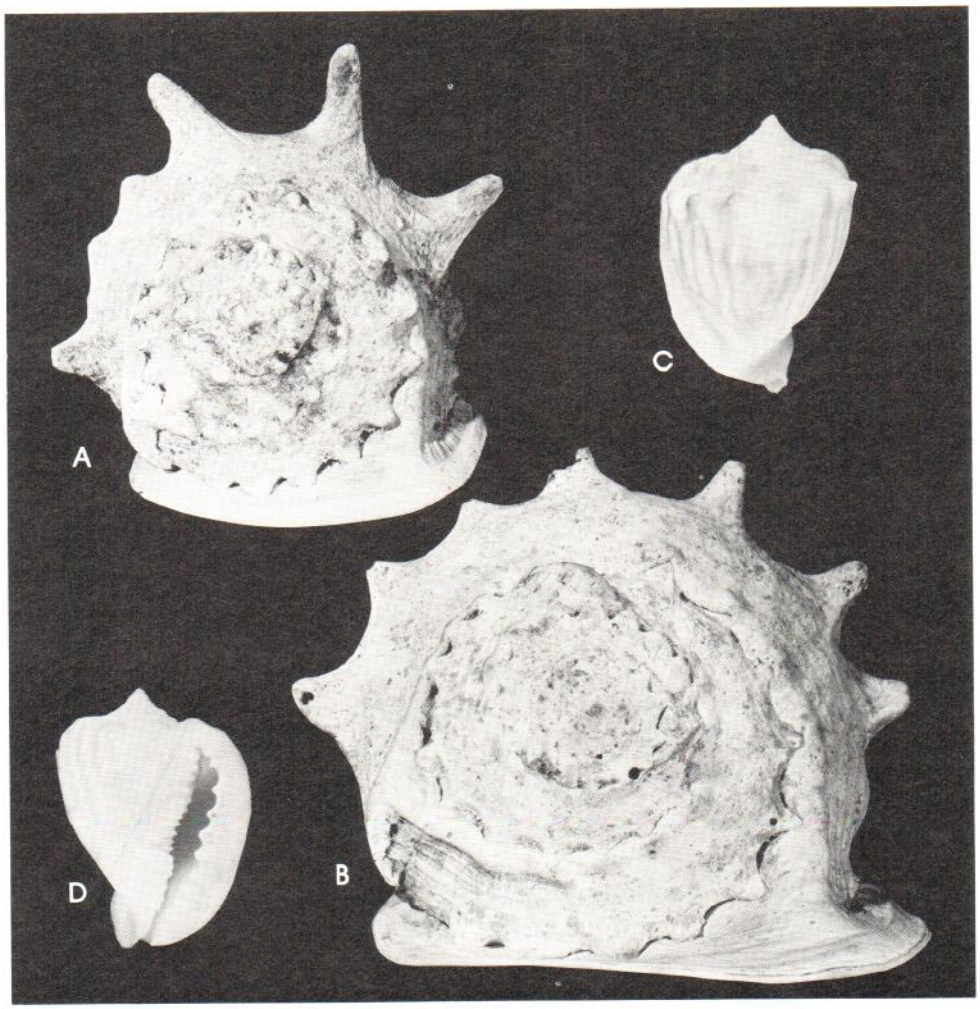


Figure 74.—*Cassis cornuta*. A. Male shell. B. Female shell. C, D. Juvenile shell, length 27 mm.

Family **Cassididae**

The helmet shells are large and handsome, solid, porcelaneous, and globose, with a flat to moderately high spire. The inner lip has a wide, shelflike callus, and varices are developed in most species. There is a small, semicircular, corneous operculum.

One of the six species found in Hawaiian waters is endemic, *Phalium umbilicatum;* the others are widely distributed in the Indo-West Pacific. The animals live in moderately deep water, usually on sandy bottoms. They are carnivorous, feeding on echinoids such as sea urchins and sand dollars, either crushing or boring through the tests.

Casmaria erinaceus kalosmodix (Melvill, 1883). Fig. 75 D, E. Length, 74 mm; diameter, 45 mm. *Shell:* elongate, solid, glossy; smooth or noduled at the shoulder;

with small denticles at the base of the varixed outer lip; white with axially oriented brown blotches below the suture, varix banded brown and white. *Spire:* protoconch of three whorls; teleoconch of five inflated whorls; suture linear. *Sculpture:* smooth or strongly noduled at the shoulder. *Aperture:* columella with four or five wrinkles; base of outer lip with four to six small denticles. *Color:* white, cream, or tan with dark brown axially oriented rectangular blotches and darker square spots on the varix; aperture violet in live-collected shells, brownish in older shells.

These cassids are found at moderate depths in sand. Shells from Midway to Necker are of unusually large size, reaching lengths of 103 mm and are progressively smaller southeast among the windward islands (Abbott, 1968). Ostergaard (1928) reports shells from Pleistocene deposits on Oahu which may represent this species.

C. erinaceus ranges through the Indo-West Pacific from the east coast of Africa into the Pacific. Abbott (1968) recognizes three subspecies, *C. e. erinaceus* in the Red Sea and East Africa, Melanesia and Micronesia; *C. e. kalosmodix* in Polynesia and Hawaii, and *C. e. vibexmexicana* on the west coast of the Americas.

This cassid is distinguished from *C. ponderosa* by its more elongate shape, less globose whorls, the restriction of the denticles on the outer lip to the basal portion of the lip, and its lack of square brown spots both on the base of the last whorl and just below the suture, characteristic of *C. ponderosa*.

Casmaria ponderosa (Gmelin, 1791). Fig. 75 F, G. Length, 37 mm; diameter, 23 mm. *Shell:* ovate-elongate; glossy; occasionally noduled at the shoulder; outer lip with 1 to 2 rows of denticles; white with a subsutural and a basal spiral row of squarish brown blotches, varix banded brown and white. *Spire:* protoconch of 3 whorls; teleoconch of 5 somewhat inflated whorls, suture linear. *Sculpture:* smooth or with axial nodules at the shoulder of the last whorl. *Aperture:* outer lip varixed and with 1 or 2 rows of denticles extending its length; columella with numerous spiral wrinkles. *Color:* white or cream with a spiral row of 7 to 9 chestnut blotches below the suture and on the base of the last whorl, sometimes with brown bands or spots between; varix with 7 to 10 chestnut or black spots.

These cassids are seldom taken alive; they live in sand at moderate depths. *C. ponderosa* occurs in Pleistocene fossil deposits on Lanai (Abbott, 1968).

C. ponderosa is distributed throughout the Indo-West Pacific from the east coast of Africa to southern Japan, Micronesia and Polynesia.

Cassis cornuta (Linnaeus, 1758). Fig. 74. Length, 300 mm; diameter, 200 mm. *Shell:* ponderous, helmet-shaped; with a flaring, callused lip; cream, callus orange-pink. *Spire:* depressed, truncate. *Sculpture:* three rows of tubercles on the last whorl, the tubercles longest on the shoulder; surface in young shells finely sculptured but usually eroded in older animals. *Aperture:* narrow; strongly toothed. *Color:* aperture and callus pink-orange and glossy; exterior cream marked with brown.

These cassids live in sand at depths of 3 to 65 m. They are often found in beds of *Pinna*. Smaller (225 mm), long-knobbed shells are those of males; larger (300 mm), short-knobbed shells are those of females.

C. cornuta is a well-known species in the Indo-West Pacific, found from the east coast of Africa to Australia, Japan, Micronesia, and Polynesia.

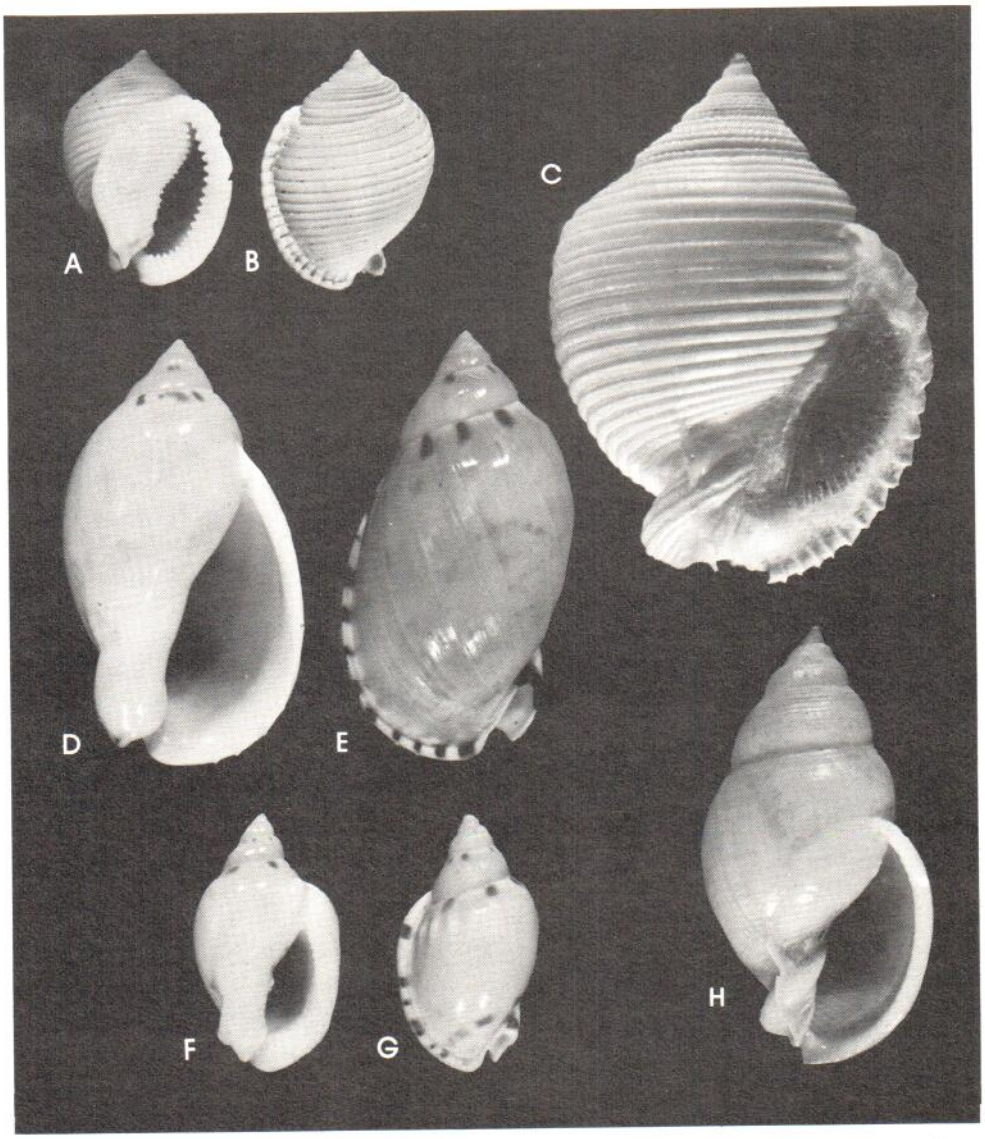


Figure 75.—**Cassididae.** A, B, C. *Phalium umbilicatum*, length 66 mm (A, B); juvenile shell without columellar callus, length 70 mm (C). D, E. *Casmaria erinaceus kalosmodix*, length 74 mm. F, G. *C. ponderosa*, length 37 mm. H. *Phalium bulla*, length 75 mm.

Phalium (Semicassis) bulla (Habe, 1961a). Fig. 75 H. Length, 75 mm; diameter, 37 mm. *Shell:* elongate-ovate, thin, glossy; with a strong, smooth varix; cream. *Spire:* protoconch of four glossy, fawn, bulimoid whorls; teleoconch of about six convex whorls; suture deep. *Sculpture:* apical whorls of teleoconch with six or seven beaded spiral threads which become obsolete on the later whorls. *Aperture:* narrow, bounded by a smooth varix; umbilicus deep. *Color:* pale fawn with darker blotches on the left edge of the columellar shield.

These cassids live in deep water and shells have been dredged from depths of 60 meters off Oahu.

P. bulla was described from Tosa, Japan, at depths of 100 to 200 m (Habe, 1961b). Abbott (1968) considers the taxon a subspecies of *P. glabratum* (Dunker, 1852a) with the nominate subspecies *P. g. glabratum* from the Philippines, Indonesia, and New Guinea; a second subspecies *P. g. angasi* (Iredale, 1927) from the north and eastern coasts of Australia; and *P. g. bulla* from southern Japan, southeast China and Hawaii. Cernohorsky (1978c, in Schoenberg) considers the Hawaiian shells different from *P. glabratum* and refers to them as a subspecies of *P. angasi*. I consider the Hawaiian and Japanese shells distinct in features of shell shape, sculpture and protoconch, and suggest that referring them to a subspecies of a more widely distributed species is premature.

Phalium (Semicassis) umbilicatum (Pease, 1861b). Fig. 75 A, B, C. (Synonym: *Semicassis fortisulcata* Smith, 1904.) Length, 66 mm; diameter, 46 mm. *Shell:* globose; with coarse spiral cords; cream. *Spire:* protoconch of three smooth, glassy, mauve to brownish purple bulimoid whorls; teleoconch of five convex whorls; suture narrow and channelled. *Sculpture:* apical whorls with four to six beaded spiral threads; last whorl with 17 to 19 strong, smooth, flat-topped spiral cords. *Aperture:* narrow, somewhat constricted; varix heavy, recurved, with 17 to 19 spiral cords which continue inside the aperture; columellar shield well-developed, lirate and rugose, parietal wall with spiral cords; umbilicate. Operculum yellow and with numerous radial, tubular folds. *Color:* cream to brown with a purple-gray blotch on the dorsal side of the penultimate whorl.

These gastropods are common at depths of 20 to 200 meters. Pleistocene fossils are found on Lanai (Abbott, 1968).

P. umbilicatum is endemic to the Hawaiian Islands.

Additional Record

Shells of *Phalium coranadoi wyvillei* (Watson, 1886) were reported dredged from depths of 211 m off Maui (Wolfe, 1974).

Family **Cymatiidae**

The triton shells are recognized by their fusiform-ovate shape, prominent varices, and elaborate spiral and axial sculpture. They lack an anal sulcus or posterior canal characteristic of the Bursidae. The operculum is horny with an eccentric nucleus and there is a fibrous or hairy periostracum covering the shell.

These mollusks are carnivorous, feeding on mollusks and echinoderms. They paralyze their prey with an acid fluid extruded from large salivary glands (Houbrick and Fretter, 1969).

Tritons pass through an efficient, free-swimming larval stage, and they have large protoconchs associated with gastropods with wide distribution. *Cymatium nicobaricum* in the Atlantic has a planktonic existence of 320 days (Scheltema, 1971). The protoconchs of premetamorphic veligers are often decorated with spines (Fig. 76 B),

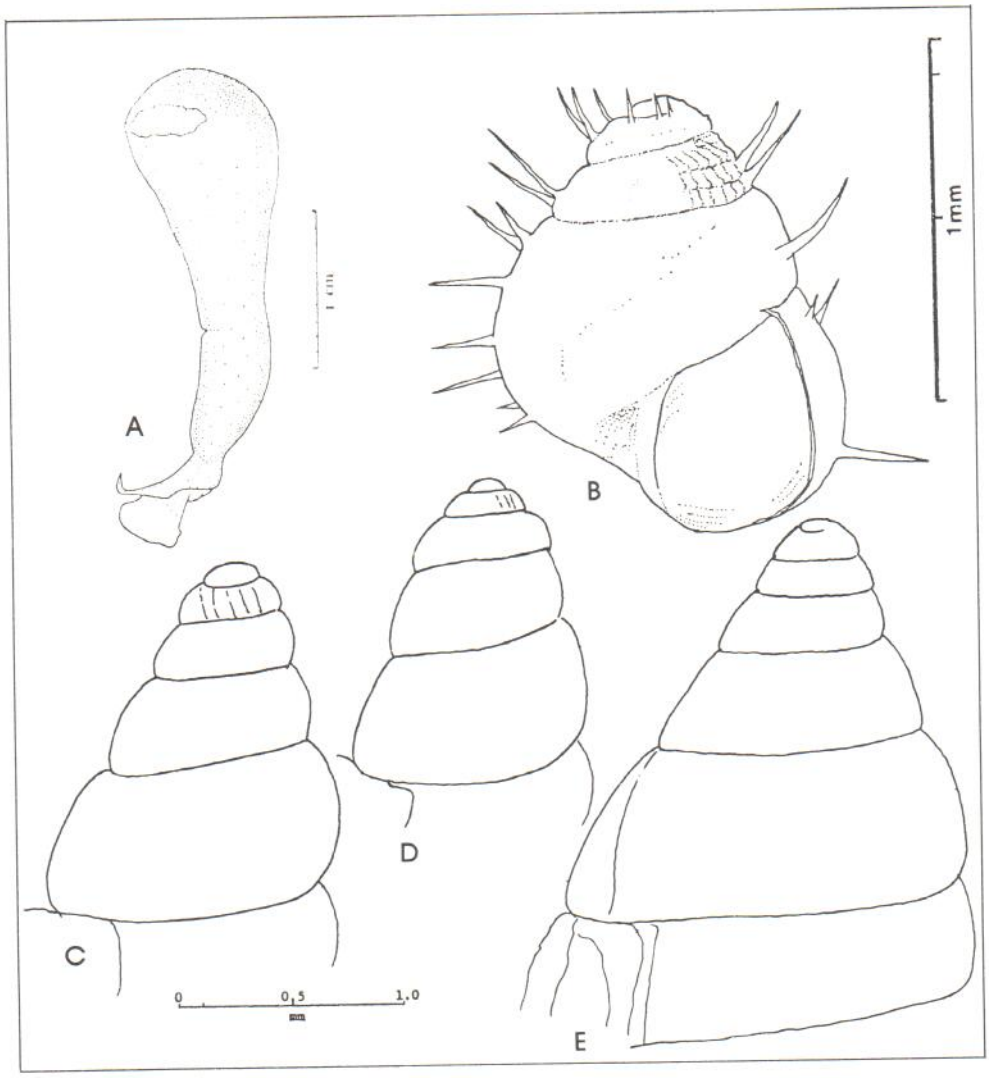


Figure 76.—**Cymatiidae.** A. Egg capsule of *Charonia tritonis* (from Berg, 1971a). B. Premetamorphic protoconch of *Cymatium nicobaricum* (Taylor, 1975). C, D, E. Protoconchs to same scale of *C. intermedius* (C); *C. pileare* (D), and *C. aquatile* (E).

but there is little or no indication of these decorations on the protoconchs of adults (Figs. 76 C-E). Nine of the 14 Hawaiian tritons are representative of species which occur in the western Atlantic Ocean and along the coast of the Americas in the eastern Pacific, as well as throughout the Indo-West Pacific.

Charonia tritonis (Linnaeus, 1767). Figs. 76 A; 77 F. Length, 500 mm; diameter, 200 mm. *Shell:* massive, ovate; with flat spiral cords; outer lip flared; tan with white and spirals of brown. *Spire:* elevated, acute; last whorl large; suture distinct. *Sculpture:* flat spiral cords separated by shallow, subequal grooves with a single

narrow thread in each interspace; occasional low, rounded axial varices spaced about 270° around the shell, sometimes bearing the remains of the outer flared lip. *Aperture:* ovate, outer lip expanded, occasionally with lirae; columella plicate. *Color:* tan, blotched or spotted with white and brown on the spiral cords; aperture orange-red; columella striated with dark brown. Periostracum scaly, brown.

C. tritonis is common at moderate depths of from 3 to 25 m and more, and specimens are occasionally found near the edge of reefs or in shallow water along surf-beaten coastlines. These tritons feed on starfish and sea urchins such as *Acanthaster, Culcita,* and *Heterocentrotus*. The egg capsules deposited in the laboratory in December are club-shaped, 25 mm long, 9 mm at the greatest diameter and 5 mm at the stalk, attached by flattened bases in groups of as many as 24 (Berg, 1971a). Metamorphosis apparently occurs when the protoconch exceeds 1500 μm in length, when two and one-half to three whorls are complete (J. B. Taylor, 1975).

Two similar forms occur in the Indo-West Pacific and Atlantic, and Beu (1970a) considers *C. variegata* (Lamarck, 1816) from the Atlantic a subspecies of *C. tritonis*.

This is the second largest gastropod found in the Indo-West Pacific, with shells reaching a length of more than 500 mm.

Cymatium (Cymatium) nicobaricum (Röding, 1798). Figs. 77 D; 82 A. (Synonym: *Cymatium chlorostomum* Lamarck, Pilsbry, 1921.) Length, 62 mm; diameter, 30 mm. *Shell:* spire equal in length to the aperture and siphonal canal; solid and heavy, with strong, prominent axial ribs and varices; aperture and columella bright orange. *Spire:* protoconch of five strongly convex whorls, the suture barely indented; teleoconch elongate and acute with seven somewhat angular whorls, convex apically; suture impressed. *Sculpture:* five to eight strong varices arranged in three directions and crossed by strong, nodulose spiral cords and finer spiral threads; varices spaced two-thirds of a whorl apart. *Aperture:* subcircular; outer lip thickened and denticulate with a single series of large teeth; columella denticulate, with the plicae extending to the parietal wall; siphonal canal moderately long and gently curved. *Color:* white, flecked and blotched with red-brown; aperture and columella bright orange, teeth white. Shell often covered with a thick, calcareous deposit. Periostracum thin, red-brown, with bristly hairs. *Animal:* tan to dark brown blotches on a white background; sole of foot with lighter spots; edge of mantle skirt bordered with large, white papillae (Houbrick and Fretter, 1969).

A common shallow-water species, *C. nicobaricum* occurs under rocks in sandy areas and shoreward on fringing reefs; specimens have also been dredged from depths of 100 m. These tritons feed on a wide variety of gastropods (Houbrick and Fretter, 1969).

This species occurs through the Indo-West Pacific and in the western Atlantic (Abbott, 1974).

Cymatium (Gutturnium) gutturnium (Röding, 1798). Fig. 78 A. Length, 60 mm; diameter, 41 mm. *Shell:* spire about one-third the length of the aperture and siphonal canal; with coarse, nodular axial ribs and spiral cords; white. *Spire:* low, compressed; suture depressed. *Sculpture:* coarse, nodular axial ribs crossed by rough spiral cords. *Aperture:* large, ovate; outer lip with coarse denticles; apical edge of peristome flat; parietal peristome raised; columella plicate. *Color:* white with axial brown streaks; aperture pale pink to brilliant orange-red.

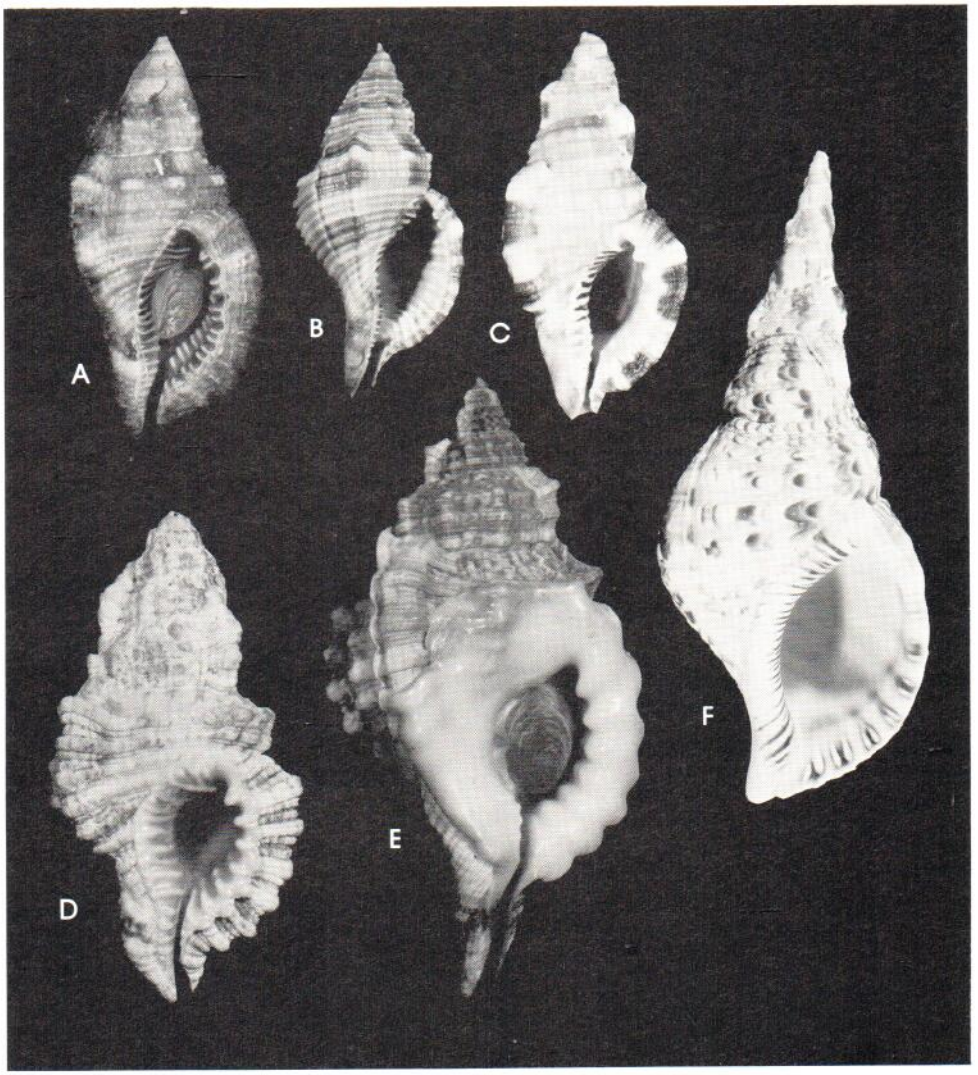


Figure 77.—**Cymatiidae.** A. *Cymatium aquatile,* length 50 mm. B. *C. pileare,* length 41 mm. C. *C. intermedius,* length 58 mm. D. *C. nicobaricum,* length 62 mm. E. *C. muricinum,* length 58 mm. F. *Charonia tritonis,* length 500 mm.

Specimens are rarely found in Hawaiian waters, recorded at depths of about 30 meters.

C. gutturnium is found throughout the Indo-West Pacific.

Cymatium (Gutturnium) muricinum (Röding, 1798). Fig. 77 E. (Synonyms: *Triton productum* Gould, 1852; *Cymatium tuberosum* Lamarck, Bryan, 1915.) Length, 58 mm; diameter, 21 mm. *Shell:* ovate, spire about half the length of the aperture and siphonal canal; with a conspicuous columellar callus; whorls, varices, and ribs sharply angular; brown with an orange aperture. *Spire:* protoconch of five and one-half

inflated, bulimoid whorls which are white with dark brown at the suture; teleoconch low, short, the last whorl larger than the others; suture distinct. *Sculpture:* sharply keeled axial ribs crossed by fine spiral threads; six or more rounded varices. *Aperture:* small; outer lip and columella heavily callused; outer lip with strong denticles; columella plicate; parietal wall with one or two denticles; siphonal canal long and recurved. *Color:* light brown, aperture orange or red, columellar callus creamy, teeth, lips and columella polished white. Periostracum thin and hairy. *Animal:* pigmentation pattern of tan to dark brown blotches on a white background.

This is a common species which occurs in sandy areas in shallow water and on reef flats. In the laboratory it feeds on the bivalves *Isognomon* and *Ostrea* (Houbrick and Fretter, 1969).

C. muricinum occurs throughout the Indo-West Pacific and in the western Atlantic (Clench and Turner, 1957).

Cymatium (Gutturnium) pyrum (Linnaeus, 1758). Fig. 78 B. Length, 66 mm; diameter, 33 mm; aperture and canal, 55 mm. *Shell:* pyriform, spire about one-third the length of the aperture and siphonal canal; with four solid varices and spiral cords; orange-red with white. *Spire:* low, compressed; whorls angulated; suture shallow. *Sculpture:* sharp axial ribs and four rounded varices crossed by spiral cords and sharp fine spiral threads abapically. *Aperture:* ovate, broad; outer lip thickened with about seven coarse denticles extending into aperture; columella callused and plicate; parietal wall with a single denticle; siphonal canal long and curved. *Color:* orange-red or orange-brown, often with white spots on the varices; aperture and teeth light-colored or white. Periostracum thin, brown, and with bristles on the varices.

Specimens of *C. pyrum* are uncommon at depths of 20 to 28 m.

C. pyrum occurs throughout the Indo-West Pacific.

Cymatium (Gutturnium) sarcostomum (Reeve, 1844). Fig. 78 C. Length, 90 mm; diameter, 40 mm. *Shell:* spire about one-third the length of the aperture and siphonal canal; with coarse, nodular axial ribs and spiral cords; orange to brown, aperture white to orange. *Spire:* low, compressed, whorls angulated on the apical part; suture adpressed. *Sculpture:* two solid, round varices; coarse, nodular axial ribs crossed by rough spiral cords forming tubercles where they cross the ribs on the upper part of the whorls. *Aperture:* ovate; outer lip thick and with a distinct row of thick denticles; apical edge of peristome extending over the last whorl; parietal wall and columella plicate. *Color:* orange-brown; aperture pale flesh-colored.

Specimens are rare in Hawaiian waters, recorded at depths of about 30 m.

C. sarcostomum occurs throughout the Indo-West Pacific.

Cymatium (Linatella) cingulatum (Lamarck, 1822). Fig. 79 A. Length, 53.5 mm; diameter, 34 mm. *Shell:* ovate, almost globose, light and thin; spire less than one-half the length of the aperture and siphonal canal; with alternating larger and smaller spiral cords; outer lip flaring; fawn axially streaked with white. *Spire:* short; whorls inflated; suture indented and deep. *Sculpture:* alternating larger and smaller spiral cords, some obsoletely granuled, especially at the apex; two or three obsolete axial folds but only the terminal varix. *Aperture:* ovate, outer lip flaring, crenulate at the edge, forming a

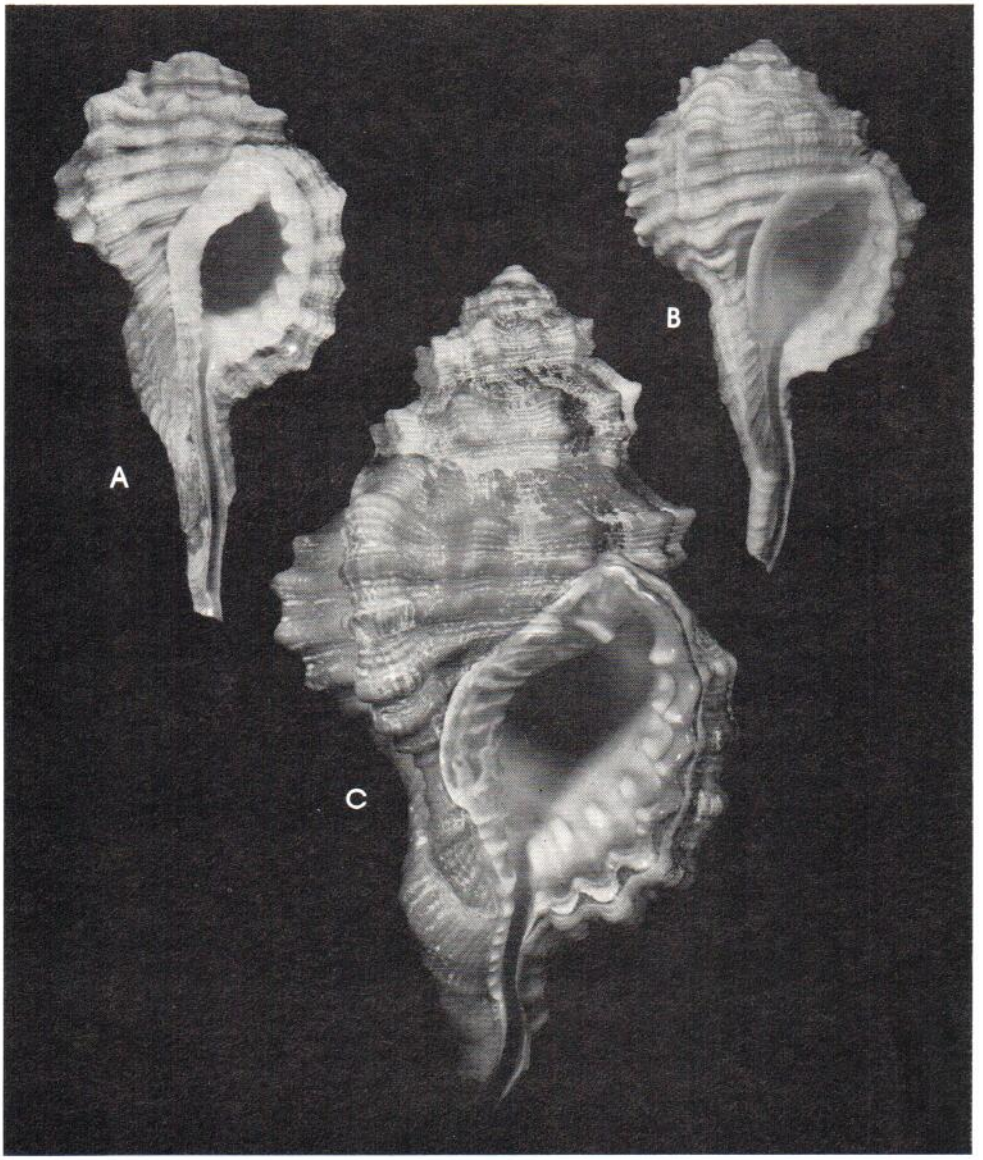


Figure 78.—**Cymatiidae.** A. *Cymatium gutturnium,* length 60 mm. B. *C. pyrum,* length 66 mm. C. *C. sarcostomum,* length 90 mm.

flange; columella smooth; siphonal canal long and recurved. *Color:* fawn, axially streaked with white; aperture white.

C. cingulatum occurs at depths of 30 to 50 m usually in beds of *Pinna.*

Beu (1976) records this species from depths of 30 to 100 m on the continental shelf throughout the Indo-West Pacific and as a common cymatiid fossil in New Zealand; it is also found from the east coast of North America from North Carolina to Brazil and in Bermuda (Abbott, 1974).

Cymatium (Linatella) clandestinum (Lamarck, 1816). Fig. 79 B. Length, 62 mm; diameter, 33 mm. *Shell:* ovate; spire just shorter than the aperture and siphonal canal; corded by equidistant ridges and with a single axial varix; light brown with darker spiral bands. *Spire:* elevated and acute; whorls inflated and convex; suture impressed. *Sculpture:* encircled by equidistant, narrow, prominent cords separated by interspaces of equal diameter; the spiral cords may be obsoletely beaded. *Aperture:* ovate; outer lip barely folded in, denticulate; siphonal canal moderately long and recurved. *Color:* light yellow-brown, banded with darker brown; aperture white, the outer lip with dark brown lirations. Periostracum yellow-brown and membranous, covering the entire shell and extending more than 1 cm beyond the aperture.

Specimens of *C. clandestinum* occur in moderately deep water, usually at depths of 12 to 15 m, but specimens have also been dredged as deep as 40 m. They are found in the cracks and crevices of old, crumbled coral heads where they are well camouflaged by the silky, brown periostracum (Harrison and Harrison, 1966).

C. clandestinum is distributed in the Pacific from the Philippines to southern Japan, Micronesia, and Polynesia.

Cymatium (Septa) aquatile (Reeve, 1844). Figs. 76 E; 77 A. Length, 75 mm; diameter, 30 mm. *Shell:* fusiform-turreted, spire equal in length to the aperture and siphonal canal; with granular spirals and prominent varices; yellow-brown, banded with lighter brown. *Spire:* protoconch of six and one-half large, conical whorls tapering apically; spire of teleoconch moderately extended and acute; whorls convex, depressed toward the apex; suture shallow. *Sculpture:* six or seven prominent varices between which are three to five granular axial ribs of lesser diameter; varices and ribs crossed by granular ribs of varying size. *Aperture:* ovate; outer lip thick and denticulate; denticles discrete, not extending into aperture; columella and parietal wall strongly plicate. *Color:* variable — yellow-white, brown often banded with the same colors; aperture light orange with white denticles; columellar plicae white, interspersed with orange.

These tritons are rarely found in Hawaiian waters, occurring at depths of more than 10 meters. *C. aquatile* is a common species throughout the Pacific.

C. aquatile is one of three species which have long been confused. Shells of *C. intermedia* Pease, 1860 and *C. pileare* (Linnaeus, 1758) resemble those of *C. aquatile* in shape, size, and sculpture but differ in details of apertural sculpture and color (Wolfe, 1975a), and in the size and shape of the protoconch. The distinguishing features of the three species are shown in Table 1 and Fig. 76.

Cymatium (Septa) intermedius (Pease, 1869b). Figs. 76 C; 77 C. (Synonym: *Cymatium pileare* (Linn.) Morris, 1966.) Length, 58 mm; diameter, 28 mm. *Shell:* fusiform-turreted, spire equal in length to the aperture and siphonal canal; with granular spiral threads and prominent varices; yellow-brown banded with white; aperture with short denticles; usually bifid; columella plicae white, interspaces black. *Spire:* protoconch of six broadly conical whorls, apical whorls sometimes with axial threads; spire moderately extended and acute; whorls convex, depressed apically; suture shallow. *Sculpture:* six or seven varices between which are three to five granular axial ribs of lesser diameter; varices and ribs crossed by granular spiral threads of varying diameter. *Aperture:* ovate, outer lip thickened and denticulate,

TABLE 1

DISTINGUISHING FEATURES OF THE THREE SPECIES OF CYMATIUM

	DENTICLES	COLOR	PROTOCONCH
C. aquatile	short, bifid	aperture and columella orange-pink; denticles and plicae white	six and one-half whorls
C. intermedius	short, single	aperture and columella orange-pink, columella slashed with black	six whorls
C. pileare	long, extending into throat	aperture and columella deep orange; columella streaked with black	six whorls

denticles discrete, not extending into aperture; canal slightly twisted; columella and parietal wall strongly plicate. *Color:* variable — yellow to brown, often banded with darker shades; aperture orange-red, denticles white; columella plicae white, stained with black in the interspaces. Periostracum thin and bristly. *Animal:* white blotched with tan and dark brown.

These tritons are common in tide pools and on fringing reefs and have been dredged from depths of 30 m. They feed on bivalves such as *Crassostrea, Ostrea,* and *Isognomon* in the laboratory (Houbrick and Fretter, 1969, as *C. pileare). C. intermedius* occurs in Pleistocene fossil deposits on Oahu and Molokai (Ostergaard, 1928, 1939).

C. intermedius was described from the Hawaiian Islands but occurs elsewhere in the Pacific in the Philippines, and Guam, and in the Marshall, Line and Marquesas islands. This species is apparently much more common in Hawaii than in other Pacific localities, where *C. aquatile* and *C. pileare* are common.

Cymatium (Septa) pileare (Linnaeus, 1758). Figs. 76 D; 77 B. (Synonym: *Cymatium vestitum insulare* Pilsbry, 1921.) Length, 41 mm; diameter, 20 mm. *Shell:* fusiform-turreted; spire equal in length to aperture and siphonal canal; with granular spiral cords and prominent varices; red-brown banded with white, columella with white and black lirae extending into the aperture. *Spire:* protoconch of six narrow, conical, olive-brown whorls; spire of teleoconch moderately extended and acute; whorls convex, depressed apically; suture shallow. *Sculpture:* six to seven prominent, beaded varices between which are three to five granular axial ribs of lesser diameter and weakly beaded spiral cords. *Aperture:* ovate, outer lip thick, denticles extending as lirae into the aperture; columella and parietal wall plicate. *Color:* yellow-white, often banded with darker yellow; aperture orange-brown or orange-red with white denticles; parietal wall dark brown, plicae white.

These tritons are uncommon in shallow water but are frequent in dredge hauls at depths of 16 to 50 m off leeward Oahu. *C. pileare* has not been recorded from the leeward islands.

C. pileare is circumtropical in distribution, found throughout the Indo-West Pacific, in the Atlantic from South Carolina to Texas, Brazil, and Bermuda, and in the eastern Pacific from the Gulf of California to Panama (Abbott, 1974). The Hawaiian shells are smaller than those found elsewhere in the Pacific: average length of the Hawaiian shells is 41 mm, average length of shells from other Pacific Islands is 69 mm.

Cymatium (Septa) gemmatum (Reeve, 1844). Fig. 79 C. Length, 30 mm; diameter, 15 mm. *Shell:* spire approximately equal in length to the aperture and siphonal canal; with irregularly arranged axial ribs and varices crossed by spiral threads; white to yellow-orange. *Spire:* protoconch of four cream or light yellow whorls, microscopically axially striated, somewhat irregular and inflated; teleoconch elevated, acute, whorls inflated and angular, suture impressed. *Sculpture:* one large varix extending on the apertural surface of the last whorl from the columella to the penultimate whorl and several smaller varices and knobs irregularly distributed on the other whorls; spiral cords sharp, sometimes noduled; cords and interspaces overridden by fine axial riblets. *Aperture:* elliptical, outer lip with 12 denticles grouped in pairs; columella plicate; parietal wall with a single denticle; siphonal canal moderately long, narrow, gently recurved. *Color:* white to yellow-gray, aperture and teeth white. Periostracum thin and straw-colored, forming fringed blades on the varices. *Animal:* red-brown spots on a yellow background.

These tritons are fairly common in shallow water shoreward of fringing reefs and to depths of 7 m. In the laboratory they feed on two species of miters (Houbrick and Fretter, 1969).

C. gemmatum occurs in both the Indo-West Pacific and western Atlantic (Bayer, 1933; Clench and Turner, 1957).

Cymatium (Septa) parthenopea (von Salis, 1793). (Not figured.) Length, 67 mm; diameter, 33 mm. *Shell:* ovate-fusiform, spire about equal in length to the aperture and siphonal canal; with axial ribs and spiral cords; light brown, outer lip with brown spots and white denticles. *Spire:* of six or seven convex whorls; suture shallow. *Sculpture:* spiral sculpture dominant, of elevated, cordlike and nodulose spiral cords; axial ribs weak, distinct on the apical whorls, becoming obsolete on the last whorl; sutural ramp with numerous fine spiral threads; varices poorly developed. *Aperture:* ovate; outer lip and columella plicate. *Color:* light brown, banded with lighter brown; columella dark red brown with white plicae; outer lip with five to seven brown spots and white denticles; periostracum thick, dark brown.

This cymatid is rare in Hawaiian waters, known only from a few shells dredged in deep water.

Beu (1970b) recognizes three subspecies, *Septa p. parthenopea* from the Mediterranean, eastern and western Atlantic, South Africa, and Australia; *S. p. echo* from southern Japan; and *C. p. keenae* from central eastern America and the Galapagos Islands.

Cymatium (Septa) rubeculum (Linnaeus, 1758). Fig. 79 D. Length, 41 mm; diameter, 23 mm. *Shell:* ovate-oblong, solid, spire equal in length to the aperture and siphonal canal; with six prominent varices; lemon to orange-red with white. *Spire:* obtuse, short, apex blunt; whorls inflated, obscuring the slightly indented suture. *Sculpture:* six prominent varices crossed by narrow beaded spiral cords; the interspaces shallow and equal in diameter; with axial threads crossing the cords and producing a beaded effect. *Aperture:* ovate; outer lip thick and denticulate; columella and parietal wall plicate; siphonal canal narrow, short, and curved. *Color:* variable — red to creamy brown, often with a white band about the middle; teeth and aperture white. Periostracum thin and straw-colored, with short, bristly hairs.

Specimens are not commonly encountered, collected at depths of from 5 to 10 m, usually in dead coral. Ostergaard (1939) reports this species from Pleistocene fossil deposits on Molokai.

This species is known throughout the Indo-West Pacific and a subspecies, *C. rubeculum occidentale* Clench and Turner 1957, occurs in the western Atlantic.

Cymatium (Septa) vespaceum (Lamarck, 1822). Fig. 79 F. Length, 33 mm; diameter, 13 mm. *Shell:* ovate, slender, spire half the length of the aperture and the siphonal canal; axial varices sharp, spiral threads faintly beaded; cream with white and brown. *Spire:* protoconch of four convex whorls with the suture distinct; teleoconch elevated, whorls angular, the last whorl much the largest; suture shallow but distinct. *Sculpture:* axial sculpture of raised, noduled ribs; spiral sculpture of finely beaded threads, the interspaces with weaker threads; one or two sharp varices. *Aperture:* small, ovate; outer lip bordered by a wide varix, with denticles arranged in pairs; columella denticulate; parietal wall with a single denticle; siphonal canal long and recurved. *Color:* rosy cream, the varices banded with white and brown. Periostracum thin and hairy.

This is a deep-water species in Hawaii, collected at depths of 40 to 50 m.

C. vespaceum occurs in the West Indies (Abbott, 1974) and throughout the Indo-West Pacific. The shells are distinguished from those of *C. labiosum* by their heavier shells and shorter siphonal canal.

Cymatium (Turritriton) labiosum (Wood, 1828). Fig. 79 E. Length, 28 mm; diameter, 10 mm. *Shell:* ovate, spire about equal in length to the aperture and siphonal canal; strongly shouldered and nodular; ashy gray and brown. *Spire:* elevated, whorls angular; suture shallow. *Sculpture:* one prominent angular varix on each whorl and three or four knobs on the shoulders of the whorls; spiral cords strong and nodular with weaker beaded spirals in the interspaces. *Aperture:* subcircular; outer lip thickened, with six denticles; columella smooth; parietal wall with one denticle; siphonal canal short. *Color:* ashy gray stained with brown, aperture white.

Only two or three specimens of this species have been recorded, all dredged at depths of 60 to 100 m.

C. labiosum occurs in the western Atlantic (Abbott, 1974) as well as throughout the Indo-West Pacific.

Distorsio anus (Linnaeus, 1758). Fig. 79 K. Length, 66mm; diameter, 33 mm. *Shell:* distorted, swollen, knobby; aperture denticulate, parietal shield covering preced-

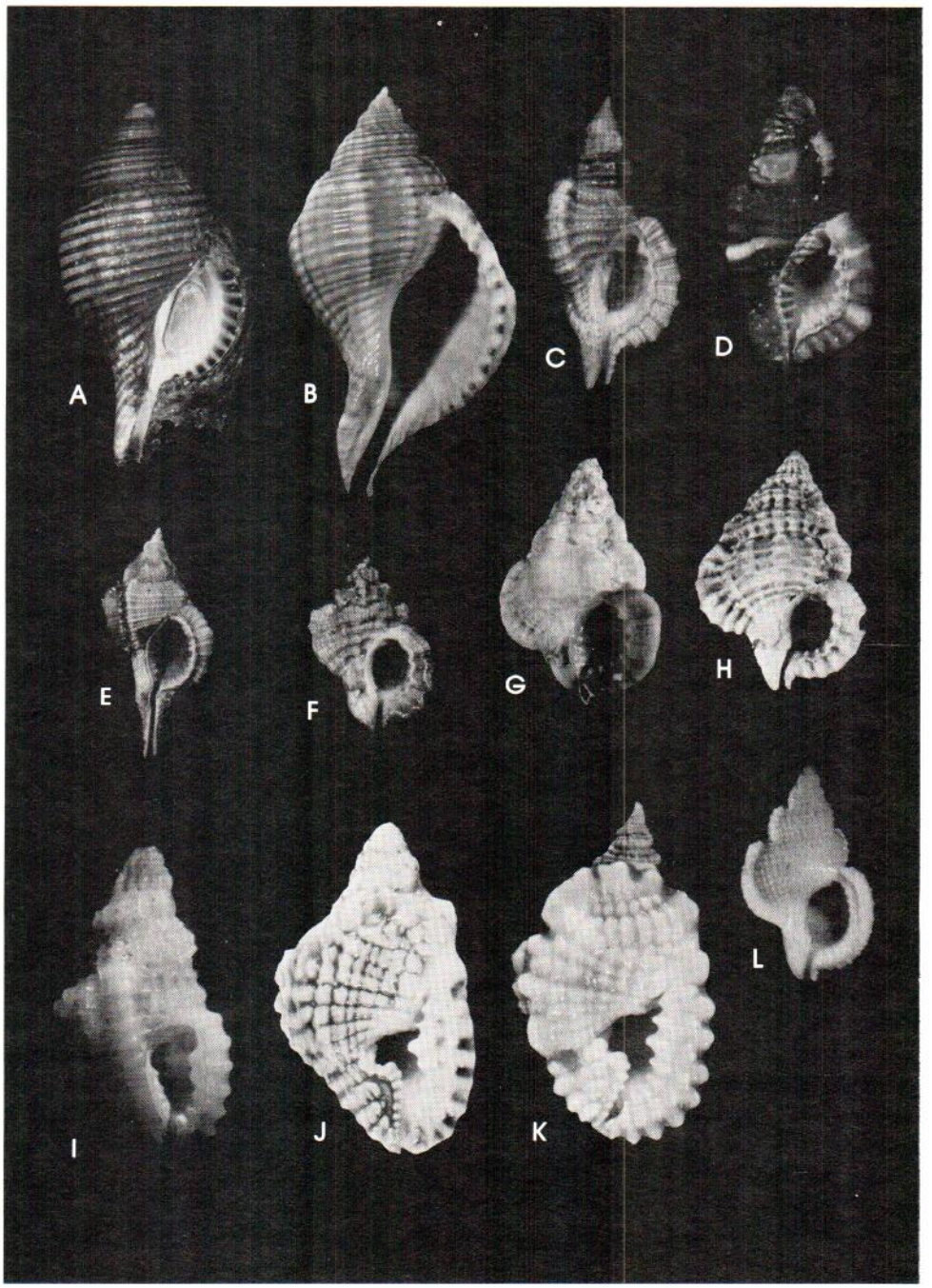


Figure 79.—**Cymatiidae.** A. *Cymatium cingulatum,* length 56 mm. B. *C. clandestinum,* length 60 mm. C. *C. gemmatum,* length 30 mm. D. *C. rubeculum,* length 40 mm. E. *C. labiosum,* length 28 mm. F. *C. vespaceum,* length 33 mm. G, H. *Gyrineum pusillum,* length 12 mm (G), 10 mm (H). I. *Distorsio pusilla,* length 10 mm. J. *D. burgessi,* length 60 mm. K. *D. anus,* length 52 mm. L. *Gyrineum louisae,* length 19 mm.

ing two whorls; white and brown. *Spire:* protoconch of three bulbous, white whorls; teleoconch short, distorted, whorls inflated and convex; suture at varying angles. *Sculpture:* spiral cords crossed by axial ribs, forming a nodular network over the surface of the shell, parietal shield with numerous axial cords. *Aperture:* small, distorted, ovate; parietal shield oval to round with deep ruffles around the perimeter, covering the preceding two whorls; outer lip denticulate, teeth jutting into the aperture and considerably condensing it; anterior canal angled and curved; siphonal canal long and recurved. *Color:* white, banded with red-brown; parietal shield white to diffused orange-tan.

These tritons are uncommon, found at depths of 10 m and more. They live in small sand pockets on hard substrates or under coral slabs (Burgess, 1963). Elsewhere in its range *D. anus* occurs in shallow water: in the Cocos-Keeling Islands Abbott (1950) recorded it from a depth of 3.6 m; in northern Australia it is found under stones on coral reefs (Allan, 1950), and in Fiji "under coral rocks on coral substrate, in shallow water" (Cernohorsky, 1967a).

Distorsio burgessi Lewis, 1972. Fig. 79 J. Length, 60 mm; diameter, 30 mm. *Shell:* distorted, swollen, knobby; aperture denticulate, parietal shield covering one and one-half preceding whorls; shell white stained with orange, parietal shield pigmented dark brown. *Spire:* teleoconch short, distorted, whorls inflated and convex; suture at varying angles. *Sculpture:* eight spiral cords crossed by 10 to 12 axial ribs; spiral rows of tubercles forming a network over the surface of the shell; parietal shield with nine spiral cords. *Aperture:* small, distorted, ovate, surrounded by a thin, flaring callus; outer lip denticulate; siphonal canal short and recurved, aligned on axis of shell. *Color:* white, stained with pale orange; parietal shield with a checkerboard pattern of dark brown. Periostracum yellowish, thin and flat, formed in a regular pattern of low hairlike processes, attached directly to the shell surface.

These tritons are found with *D. anus* to depths of 85 m in the windward islands, and are apparently common on the reef flat at Pearl and Hermes Reef in the leeward islands.

D. burgessi was described from the Hawaiian Islands.

Distorsio pusilla Pease, 1861a. Fig. 79 I. Length, 10 mm; diameter, 5 mm. *Shell:* conic-ovate; somewhat distorted; with axial ribs and nodulose spiral cords; cream to light brown. *Spire:* teleoconch of four or five slightly convex, twisted whorls; suture impressed. *Sculpture:* about seven varices, most prominent on the last whorl; relatively strong axial ribs (15 on the last whorl) crossed by nodulose spiral cords; additional cords on the siphonal fasciole; interspaces finely cancellate. *Aperture:* narrow, occluded by seven prominent denticles on the outer lip and four columellar folds. *Color:* cream to light brown.

This cymatiid is rarely found, known only from occasional beachworn shells and an occasional specimen found at depths of more than 30 m.

D. pusilla was described from the Hawaiian Islands and has also been reported from Guam (Cernohorsky, 1975b).

Gyrineum louisae Lewis, 1974. Fig. 79 L. Length, 19 mm; diameter, 12 mm. *Shell:* conical with laterally aligned varices; with a reticulate pattern of spiral cords and

axial ribs; white. *Spire:* protoconch of three and one-half convex whorls covered by a network of axial and spiral threads; teleoconch of six whorls, suture distinct. *Sculpture:* thirteen spiral cords crossed by sixteen axial ribs forming a beaded pattern. *Aperture:* outer lip thickened at final varix; siphonal canal short; denticulate. *Color:* white.

The holotype is the only specimen known and was dredged from a depth of 360 m off Pokai Bay, Oahu, Hawaii.

Gyrineum pusillum (Broderip, 1832). Fig. 79 G, H. (Synonyms: *Triton lacunatum* Mighels, 1845; *Gyrineum polychlorum* Tapparone, Edmondson, 1933.) Length, 12 mm; diameter, 9 mm. *Shell:* compressed, bordered on each side by a lateral varix; aperture purple. *Spire:* attenuate, whorls compressed, suture impressed. *Sculpture:* variable — reticulated to nodulous, with fine spiral cords crossed by axial grooves; varices forming two ribs, one on each side. *Color:* banded with white, blue, and rose; aperture purple, sometimes cream with a rosy aperture.

Specimens are not uncommonly collected under rocks in tide pools, and have been recorded to depths of 104 m.

This species is widely distributed throughout the Indo-West Pacific from the Seychelles to southern Japan and Okinawa, and Polynesia. The shells are variable in sculpture and color, and some of the forms have been assigned different names such as *G.* var. *rosea* (Reeve, 1844) and *G. cuspidataeformis* (Kira, 1956).

Additional Records

One live-collected specimen of *Cymatium (Septa) hepaticum* (Linnaeus, 1758) has been reported from Oahu (Wolfe, 1975a).

Fusitriton midwayensis Habe and Okutani, 1968, is a representative of a typically temperate genus described from depths of 400 to 460 m off Midway. The shells are 36 to 53 mm in height, 17 to 25 mm in diameter, fusiform, white with four brownish spiral cords and covered with a pale yellow, hairy periostracum.

Family **Bursidae**

The bursids lack the hairy periostracum of the Cymatiidae and are also distinguished by the presence of an anal sulcus or posterior canal in the aperture. Their curious knobbed sculpture, reminiscent of the texture of some frogs and toads, has given rise to their common name of "frog shell."

Most members of the family occur on coral reefs in the tropics, and some species, like those of the Cymatiidae, are almost circumtropical in distribution. Species of *Bursa* feed on polychaete worms and sipunculids, paralyzing their prey with a highly acid secretion from the salivary glands (Houbrick and Fretter, 1969).

Bursa bufonia (Gmelin, 1791). Fig. 80 G. (Synonym: *Ranella luteostoma* Pease, 1861a.) Length, 80 mm; diameter, 49 mm. *Shell:* somewhat depressed with lateral varices and siphonal canals; sculpture of knobbed spirals and finer threads; shell and

aperture white, cream, or yellow. *Spire:* rather obtuse, suture obscured, whorls somewhat flattened. *Sculpture:* encircled by knobbed spiral threads with finer threads between. *Aperture:* ovate; outer lip irregularly denticulate, edge frilled; columella plicate. *Color:* white or cream with brown markings; aperture white or yellow within, denticles white.

These gastropods are infrequently encountered in shallow water, and are collected at depths of 20 m. Their habitat in the Hawaiian Islands is in contrast to the habitat elsewhere in the Pacific; in Micronesia the species is recorded as "abundant along the windward shores of Bikini, Eniwetok, Rongelap, and Ronerik" (Demond, 1957).

Bursa cruentata (Sowerby, 1841). Fig. 80 B. Length, 41 mm; diameter, 26 mm. *Shell:* ovate, solid; sculpture of spiny cords; aperture white. *Spire:* five or six convex whorls; suture shallow and distinct. *Sculpture:* encircled by beaded and tubercled spiral threads, the tubercles spiny; with a lateral varix on each side. *Aperture:* ovate; sutural canal prominent; outer lip fluted and denticulate; siphonal canal recurved. *Color:* variable — white, yellow, or brown, the tubercles often spotted with red; aperture white or rosy, columella sometimes spotted with red. *Animal:* body blotched with red with scattered orange spots usually surrounded by opaque white (Houbrick and Fretter, 1969).

B. cruentata occurs at depths of from 16 to 100 m, and feeds on polychaete worms and sipunculids (Houbrick and Fretter, 1969). Shells occur in Pleistocene fossil deposits on Molokai (Ostergaard, 1939).

B. cruentata was described from the Philippines, and appears to be limited in its distribution to the Indo-West Pacific.

Bursa granularis (Röding, 1798). Fig. 80 A. (Synonym: *Ranella affinis* Broderip, Martens and Langkavel, 1871.) Length, 63 mm; diameter, 38 mm. *Shell:* dorsoventrally compressed, solid; with axially oriented lateral varices and granular spirals; pink-white. *Spire:* five or six somewhat compressed whorls; suture shallow and indistinct. *Sculpture:* encircled by spirals of small beads and tubercles and with a larger row of tubercles in the center of each whorl; a single lateral varix on each side. *Aperture:* columella plicate; outer lip irregularly denticulate. *Color:* flesh to yellow, spotted and stained with red-brown; apex rosy. *Animal:* body blotched with red with scattered orange spots surrounded by opaque white; mantle edge with small papillae (Houbrick and Fretter, 1969).

This is a commonly occurring species in tide pools and to depths of 16 m. Beachworn shells are often found inhabited by hermit crabs. *B. granularis* feeds on polychaete worms (Houbrick and Fretter, 1969).

This species has a wide distribution, occurring in south-east Florida and the West Indies (*B. granularis cubaniana* (Orbigny, 1842)) and ranging throughout the Indo-West Pacific from East Africa to the Tuamotus and Hawaii (Demond, 1957), and east to Clipperton Island.

Bursa latitudo Garrard, 1961. Fig. 80 H. Length, 200 mm; diameter, 115 mm. *Shell:* conic-ovate, turreted, accuminate; thin-shelled; with sharply noduled whorls; cream flecked with darker brown, aperture white, columella stained with dark brown. *Spire:* turreted, acuminate; teleoconch of about 10 slightly inflated whorls; suture

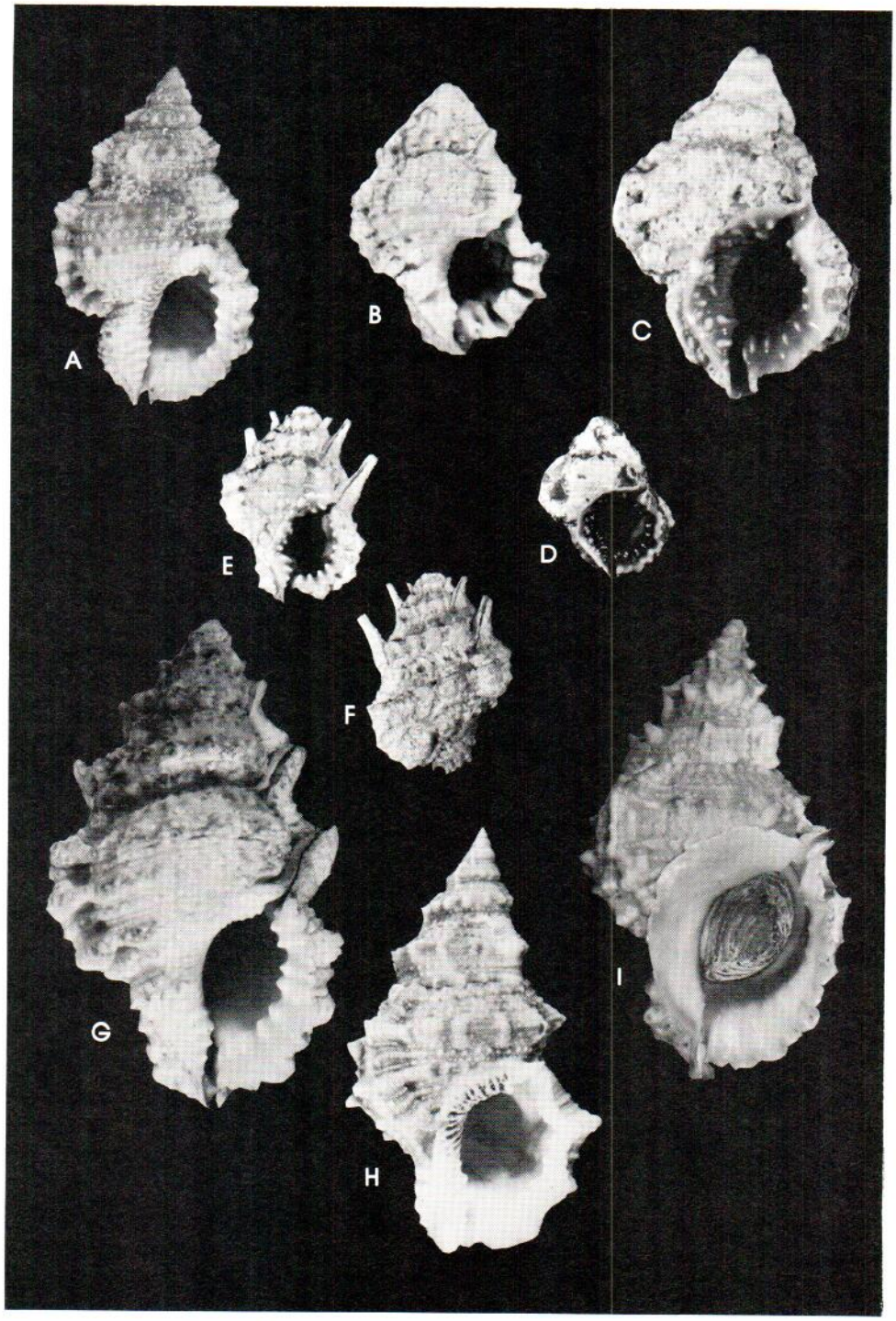


Figure 80.—**Bursidae.** A. *Bursa granularis,* length 60 mm. B. *B. cruentata,* length 40 mm. C, D. *B. rhodostoma,* length 26 mm. E, F. *B. rosa,* length 27 mm. G. *B. bufonia,* length 80 mm. H. *B. latitudo,* length 200 mm. I. *Tutufa bufo,* length 160 mm.

shallow. *Sculpture:* axial ribs becoming most prominent about the periphery of each whorl, about ten on the last whorl, crossed by narrow spiral threads; about four prominent varices. *Aperture:* ovate; outer lip expanded and fluted; columella with irregularly arranged plicae. *Color:* cream to fawn, flecked with darker brown, aperture white, columellar plicae stained in the interspaces with dark brown.

These bursids are uncommon, dredged at depths of 200 to 400 m.

B. latitudo was described from New South Wales.

Bursa rosa (Perry, 1811). Fig. 80 E, F. (Synonym: *Bursa siphonata* Reeve, 1844.) Length, 27 mm; diameter, 21 mm. *Shell:* somewhat depressed, with lateral varices and siphonal canals; aperture deep purple, outer lip yellow. *Spire:* short, rather blunt; suture shallow; whorls compressed with two siphons on the apertural side, one on the opposite side. *Sculpture:* prominent axial ribs and knobs between the lateral varices; spiral sculpture of fine, sharply granular cords. *Aperture:* ovate; basal canal short and recurved; outer lip frilled and denticulate within; columellar wall irregularly plicate. *Color:* cream, spotted with brown; interior of aperture purple, outer lip yellow.

A common species in shallow water in surf-beaten tide pools, *B. rosa* has also been recorded to depths of 160 m.

B. rosa occurs throughout the Indo-West Pacific.

Bursa rhodostoma Sowerby, 1841. Fig. 80 C, D. (Synonym: *Bursa venustula,* Reeve, Edmondson, 1933.) Length, 26 mm; diameter, 21 mm. *Shell:* ovate; finely spirally granular; aperture rosy with white denticles. *Spire:* short; suture shallow. *Sculpture:* prominent axial knobs centrally between strong lateral varices and beaded, spiral cords. *Aperture:* subcircular with a shallow anterior canal and a short basal canal; outer lip frilled and finely denticulate within; parietal wall irregularly plicate. *Color:* cream, spotted with brown; aperture pink-purple, plications and denticles white.

This species occurs at depths of from 13 to 160 m; specimens are often found inside dead coral heads (Anon. 1962a as *B. venustula). B. rhodostoma* feeds on polychaete worms and sipunculids (Houbrick and Fretter, 1969).

Although *B. rhodostoma* was described from the Indo-West Pacific, Abbott (1958) has suggested that the Hawaiian shells are better considered as *B. thomae* Orbigny which he believes is distributed from the western Atlantic (Grand Cayman, Florida, Santo Domingo, the Virgin Islands, and Brazil) through the Indian and Pacific Oceans (Mauritius, Marquesas).

Tutufa bufo (Röding, 1798). Fig. 80 I. (Synonyms: *Bursa lampas* Linnaeus, Tinker, 1952.) Length, 160 mm; diameter, 100 mm. *Shell:* massive, ovate; axially and spirally sharply noduled, aperture with a prominent callus; yellow, aperture pink with a red ring. *Spire:* whorls convex, angular. *Sculpture:* each whorl with two prominent and several less prominent spirals of tubercles between which are granular spirals and axially arranged varices. *Aperture:* ovate, outer lip flaring and crenulate; parietal wall heavily callused. *Color:* white to cream, clouded with orange-brown; aperture flesh to orange-red, with a red ring on pink.

T. bufo is a rare deep water species in the Hawaiian Islands, known from a unique shell from a depth of 200 m.

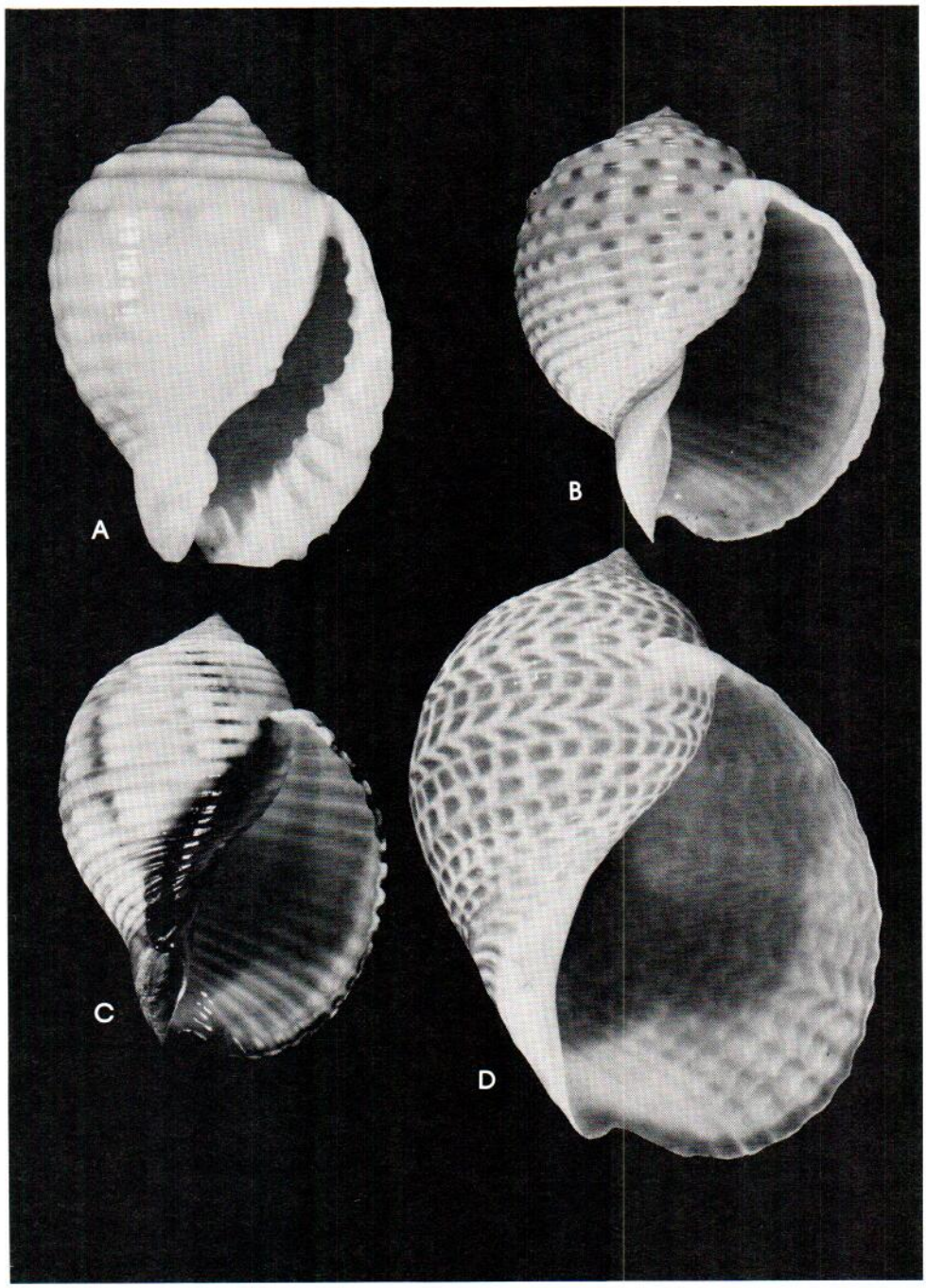


Figure 81.—**Tonnidae.** A. *Malea pomum*, length 75 mm. B. *Tonna dolium*, length 60 mm. C. *T. melanostoma*, length 110 mm. D. *T. perdix*, length 90 mm.

The ponderous shells of *T. bufo* are recognized by their large size and prominent callus; they are well known throughout the Indo-West Pacific.

Family **Tonnidae**

The tuns have light, thin, ventricose shells which are usually of large size (73 mm or more in length) and ornamented with encircling cords. The animals have prominent, fleshy mantles, and the foot protrudes from the shell. There is no operculum.

These gastropods are sand dwellers and carnivorous, feeding on sea cucumbers and bivalves. The egg masses consist of broad ribbons which contain oval, transparent eggs. The veligers hatch from the egg capsules two to three weeks after spawning and the larvae metamorphose when protoconch dimensions are more than 2 mm (J. B. Taylor, 1975). In the Atlantic two species, *T. galea* and *T. maculosa*, have planktonic stages of eight and six months respectively (Scheltema, 1971).

Of the five species of Tonnidae found in Hawaiian waters, only one, *Tonna perdix*, is common at depths of less than 10 m, and it is circumtropical in distribution.

Malea pomum (Linnaeus, 1758). Fig. 81 A. Length, 75 mm; diameter, 53 mm. *Shell:* ovate, heavy; with spiral cords; white marked with amber. *Spire:* six whorls; last whorl less expanded than in *Tonna:* suture not depressed. *Sculpture:* twelve well-defined, low, apical cords. *Aperture:* outer lip denticulate within, reflected outward and thickened; inner lip wrinkled; columella excavated at base. *Color:* white, blotched with various shades of amber which appears spotted with white on the cords; lips white; interior yellow-pink.

Specimens of *M. pomum* are found at depths of 33 m.

Pease (1871d) noted that shells of *M. pomum* are more common in the leeward islands than in the windward islands; this observation has been confirmed in recent years with collections from Midway, for instance, far exceeding those from the windward islands.

Tonna dolium (Linnaeus, 1758). Fig. 81 B. Length, 61 mm (to 150 mm); diameter, 59 mm. *Shell:* ovate, thin, ventricose; with well-defined spiral cords; white with brown spots on the cords. *Spire:* approximately six whorls; last whorl greatly swollen centrally. *Sculpture:* 12 to 16 well-defined spiral cords, the interstices of equal diameter and with or without a smaller median spiral in each groove. *Aperture:* wide; outer lip thin, crenate; lower part of columella prominently twisted. *Color:* white or blue-white, with quadrate brown spots separated by white spaces of equal size on the spiral cords; interstices darker in color than the cords.

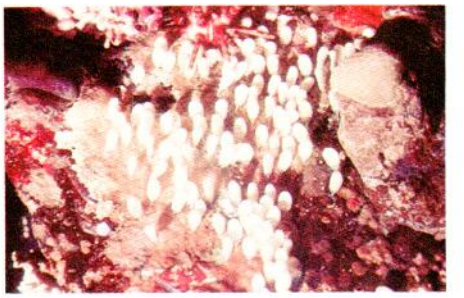
This tun occurs in deep water, at depths of more than 30 m where it is sometimes caught in fish traps on the outer edges of fringing reefs (Tinker, 1949). The shells are often frequented by hermit crabs and carry the large sea anemone *Calliactis armillatus* (Verrill).

T. dolium ranges from the Indian Ocean to the Philippines, Japan, Fiji, and New Zealand.

A

B

C



D

E

F

Figure 82.—Aspects of reproduction in the prosobranchs. A. *Cymatium nicobaricum* with egg mass. B. Egg mass of *Natica gualteriana*. C. Egg mass of *Fasciolaria* sp. D. Egg capsules of *Mitra stictica*. E. Planktonic veliger larva of a turrid. F. Planktonic veliger larva of a mitrid. (A, C, and D by O. Schoenberg; E, F by J. B. Taylor.)

Tonna melanostoma (Jay, 1839). Fig. 81 C. Length, 110 (to 230) mm; diameter, 83 mm. *Shell:* ovate, thin; white to brown with irregular bands of darker brown, parietal callus and edge of outer lip black. *Spire:* protoconch of three bulimoid, dark brown whorls; teleoconch of seven whorls; last whorl greatly inflated; spire shorter than in *T. perdix*. *Sculpture:* 18 to 20 convex cords with or without smaller, intervening ridges. *Aperture:* wide; emarginate basally; outer lip simple and crenate; columella expanded, occasionally somewhat twisted. *Color:* white, yellow, or brown, the color often in axial streaks and the interspaces darker than spiral cords, parietal callus and edge of outer lip black.

Shells are uncommonly found and are usually inhabited by the hermit crabs *Dardanus asper* de Haan and *D. puctulatus* (Oliver) (Tinker, 1949). Pease (1871d) commented that *T. melanostoma* appeared to be more common in the leeward islands than in the windward islands, and recorded ten shells from French Frigate Shoals. This observation has been confirmed in recent years, with numerous shells noted on the beaches of the leeward atolls.

T. melanostoma occurs throughout the tropical Pacific, from Melanesia and New Zealand to the Society Islands.

Tonna perdix (Linnaeus, 1758). Fig. 81 D. Length, 131 mm; diameter, 67 mm. *Shell:* ovate, thin; with flat spiral cords and shallow grooves; red-brown reticulated with white. *Spire:* protoconch of three or three and one-half globose, golden brown whorls; teleoconch of five and one-half strongly convex whorls rapidly increasing in size; suture deeply impressed. *Sculpture:* 19 or 20 flat, spiral cords separated by shallow grooves of lesser diameter. *Aperture:* wide, somewhat oblique; outer lip thin; parietal wall thinly glazed by a shield which covers the umbilicus. *Color:* usually red-brown with lines of white reticulating the surface but may be almost uniformly brown.

These tuns are the commonest representatives of the family in Hawaiian waters; they are sometimes found at depths of less than 3 m but are more abundant at depths of 5 to 10 m. *T. perdix* was reported from Pleistocene fossil deposits on Oahu (Ostergaard, 1928).

T. perdix is found throughout the Indo-West Pacific from the east coast of Africa to Micronesia and Polynesia.

Additional Record

Tonna cepa (Röding, 1798) was reported (Tinker, 1949, as *T. canaliculata* (Linnaeus, 1758)) from a single specimen with a hermit crab caught in a fish trap at a depth of 30 m.

Order NEOGASTROPODA

(STENOGLOSSA)

The order Neogastropoda is generally regarded as the most highly advanced of the prosobranch gastropods, and includes the largest living gastropod, *Melo*, shells of which may be 50 cm in length. At least 1110 Recent and fossil genera and subgenera are recognized (Taylor and Sohl, 1962).

The large number of genera and species speaks for the success of this group, which is adapted to almost every marine habitat recognized. Only a few are known from freshwater (none in Hawaii); none has invaded land. Three features, among others, of these mollusks are associated with their highly specialized modes of life. The shells are characterized by a distinct anterior siphonal canal through which the siphon, an elongation of the mantle, projects, directing water currents and their chemical signals to the osphradium at the base of the mantle cavity. The proboscis is also highly extensible and is a device which also permits these mollusks to exploit territory at some distance from their shells. In the Rachiglossa (Muricacea, Buccinacea, Volutacea, and Mitracea) the central radular tooth consists of an elongate base from which project sharply pointed cusps (Figs. 84, 101), used in some forms as drills. In the Toxoglossa or Conacea the radular teeth are slender, barbed structures (Fig. 120), and in some forms are associated with a venom gland.

Superfamily MURICACEA

The hallmarks of the muricaceans, the Muricidae, Thaididae, and Coralliophilidae, are shelly projections: varices, lamellae, and spines which project from the shell, and apertural denticles which in sexually mature animals may partially block the aperture of the shell.

All muricaceans for which the feeding habits are known are carnivorous, feeding on other mollusks and shelled invertebrates such as barnacles, echinoderms and corals. Anatomical features which are associated with their feeding habits include a long proboscis; a radula of simple lateral teeth and a broad, pectinate central tooth (Fig. 84); a bulky gland of Leiblein; two pairs of salivary glands; and an accessory boring organ on the sole of the foot which may secrete an acid, chelating agents and enzymes which aid in boring shells (Carriker and Williams, 1978). The hypobranchial gland produces a purple secretion which has a toxic component (see Halstead, 1965).

Muricaceans are, for the most part, associated with hard substrates. The foot is enlarged and adherent in the Thaididae which live on wave-swept shores, small in

free-moving subtidal forms, and reduced in the sessile, coral-associated Coralliophilidae. The sexes are separate and the eggs are deposited in capsules attached to a hard substrate.

Family **Muricidae**

The shells of the Muricidae include the most complexly sculptured of all gastropod shells, especially characterized by varices, ridges on the whorls which represent periodic thickenings of the shell. The shells are solid, ranging in shape from fusiform to elongate. The operculum is horny and roughly oval.

Three of the eight members of the family reported from Hawaiian waters are found in shallow, intertidal waters; the remaining species are found only in deep water. Six of the eight species appear to be widely distributed in the Indo-West Pacific; two are endemic to the Hawaiian region.

The Hawaiian muricids may be keyed as follows:

1. Sculpture of foliaceous or spinose projections 2
   Sculpture predominantly of ropelike axial varices 4

2. (1) Ovate, outer lip frilled or foliaceous 3
   Compressed, outer lip spinose ..... *Homolocantha anatomica*

3. (2) Shell large (90 mm); outer lip foliaceous ..... *Chicoreus insularum*
   Shell of medium size (45 mm);
   outer lip frilled ..... *Marchia martinetana*

4. (1) Shell of medium size (30 mm) or small (10 mm); depressed
   or tritonlike; with riblike varices 5
   Shell large (70 mm); varices
   compressed, finlike ..... *Pterynotus elongatus*

5. (4) Shell biconic 6
   Shell elongate, compressed; sculpture
   of riblike varices ..... *Aspella producta*

6. (5) Whorls convex; sculpture cancellate 7
   Whorls angular; sculpture of imbricated
   spiral cords ..... *Vitularia miliaris*

7. (6) Shell small (10 mm); aperture with
   frilled outer lip ..... *Favartia garrettii*
   Shell medium size (25 mm); aperture
   with denticles ..... *Muricodrupa funiculus*

Aspella producta (Pease, 1861a). Fig. 83 C, D. (Synonym: *Aspella anceps* (Lamarck), Tryon, 1881.) Length, 19 mm; diameter, 8 mm. *Shell:* elongate, dorsoventrally compressed; with varices bordering each side; surface rough; white. *Spire:* five flattened whorls; suture impressed. *Sculpture:* two varices laterally and three somewhat obsolete axial ribs crossed by spiral threads which render the ribs nodulous. *Aperture:* oval; coarsely lirate within; canal short, recurved. *Color:* white.

These muricids are common in tide pools and to depths of more than 30 m. There appear to be two shell forms, a large form with shell lengths of over 20 mm and a smaller form with shell lengths of about 10 mm (Fig. 83 C, D).

This species was described from the Hawaiian Islands, but is widely distributed from East Africa (Zanzibar) to Taiwan (Radwin and D'Attilio, 1976).

Chicoreus insularum (Pilsbry, 1921). Fig. 83 J. (Synonym: *Murex torrefactus insularum* Pilsbry, 1921.) Length, 90 mm; diameter, 58 mm. *Shell:* ovate; varices foliose, with axial ridges between; brown, often tinted with pink. *Spire:* about eight whorls; suture shallow, obscure. *Sculpture:* three sets of foliose varices which half-way encircle the spire; spiral sculpture of two sharp ridges terminating on the varix in foliations and between which are scabrous threads. *Aperture:* subcircular with a subsutural callosity; outer lip erect and frilled; interior lirate; operculum kite-shaped with the nucleus apical and the margins entire. *Color:* yellow-white to ruddy brown; foliations often tinted with pink; aperture white.

These muricids are found at depths of 40 to 160 m. They bore the bivalves *Trachycardium orbita* (Cross, 1963, as *T. hawaiiensis*) in the field and *Pinna, Spondylus* and *Periglypta* in the laboratory (Mayor, 1975).

This species is endemic to the Hawaiian Islands. Although described by Pilsbry (1921) as a subspecies of *M. torrefactus* Sowerby, 1841, Rehder (1964) suggests that the Hawaiian shells are specifically distinct because of the heavier intervaricial knobs, flexed varicial processes, and smaller processes and that they are more closely related to *C. steeriae* Reeve, 1845, from the Marquesas than to the widely distributed *C. torrefactus*.

Favartia garrettii (Pease, 1869b). Fig. 83 G. (Synonyms: *Murex exigua* Garrett, 1857, non Broderip, 1832; *Murex cyclostoma baldwiniana* Pilsbry, 1921.) Length, 10 mm; diameter, 6 mm. *Shell:* tritonlike; with eight axial varices crossed by sharp, thick spiral cords; gray. *Spire:* protoconch of two smooth, turbinate whorls; teleoconch turreted, last whorl angular, suture channeled. *Sculpture:* thin axial ribs or varices with interspaces shallow and of greater diameter; axial ribs crossed by sharp, thick spiral cords with interspaces of lesser diameter and cancellated by axial threads. *Aperture:* subcircular; outer lip thin and crenulated, lirate within; columella straight; siphonal fasciole weak. *Color:* gray, aperture with brown or dark purple.

F. garrettii occurs under stones on reefs and in tide pools.

This species was described from the Hawaiian Islands.

Homolocantha anatomica (Perry, 1811). Fig. 83 A, B. (Synonym: *Murex pele* Pilsbry, 1920.) Length, 32 mm; diameter, 23 mm. *Shell:* elongate-conic; with a long siphonal canal and palmate spines; white to ruddy brown. *Spire:* protoconch of six smooth, acutely conical whorls; teleoconch of angulated whorls; suture impressed. *Sculpture:* four axial varices fimbriated by spiny palmate projections with fine spiral threads, some granular. *Aperture:* subovate, small in comparison to the size of the shell; siphonal canal elongate, nearly closed; operculum purpuroid, concentric, the nucleus near the middle of the right side and the right edge frilled with flattened projections. *Color:* variable, white to deep salmon or ruddy brown; surface of the shell usually obscured by calcareous deposits.

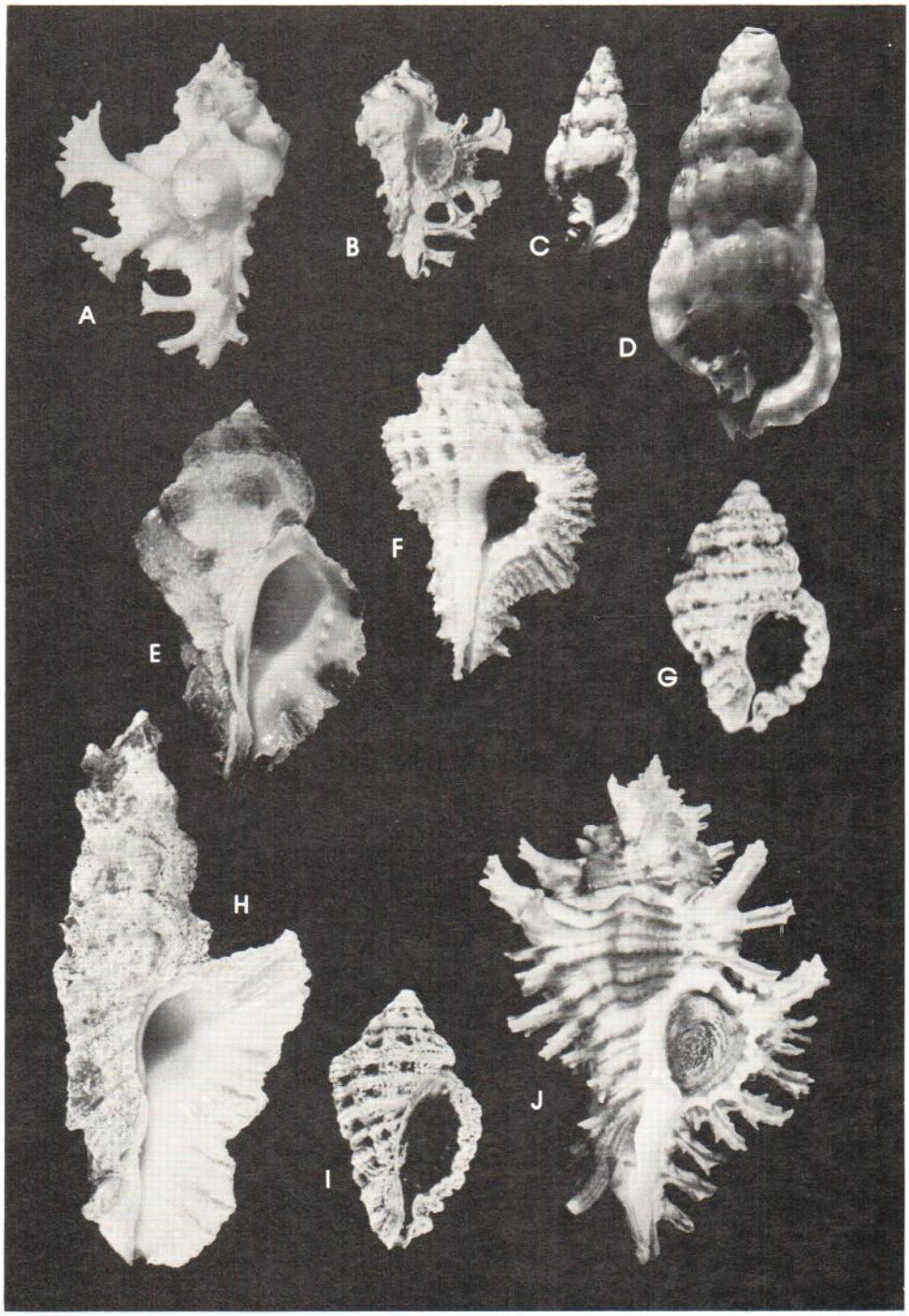


Figure 83.—**Muricidae.** A, B. *Homolocantha anatomica*, length 32 mm. C, D. *Aspella producta*, length 8 mm (C), 19 mm (D). E. *Vitularia miliaris*, length 34 mm. F. *Marchia martinetana*, length 47 mm. G. *Favartia garrettii*, length 10 mm. H. *Pterynotus elongatus*, length 90 mm. I. *Muricodrupa funiculus*, length 25 mm. J. *Chicoreus insularum*, length 90 mm.

H. anatomica occurs at depths of from 20 to 200 m. The animals appear to live on small heads of the coral *Porites,* and blend with their surroundings. Beachworn shells are uncommon in drift along the northern shores of the Islands.

Rehder (1964) regards the Hawaiian shells as representative of the widely distributed Indo-West Pacific species *H. anatomica,* recording it from the East African coast, the Philippines, southern Japan, and the Ryukyus, New Britain, and Fiji. D'Attilio (1964) considers the Hawaiian shells distinct from *H. anatomica,* retains Pilsbry's name, *H. pele,* for them, and also records the species from the southwest coast of Japan.

Marchia martinetana (Röding, 1798). Fig. 83 F. Length, 47 mm; diameter, 29 mm. *Shell:* fusoid, convex; with cordlike axial ribs and frilled varices; cream, outer lip reddish, aperture yellow. *Spire:* spire high, teleoconch of about six convex to subangulate whorls; suture weakly impressed, undulate. *Sculpture:* with four rugose varices on the last whorl and ropelike ridges between the varices; spiral sculpture of three distinct groups of major cords and numerous scabrous cords; moderately long spines forming where the spiral cords intersect the varices; outer lip with ruffled axial lamellae. *Aperture:* ovate; margin of outer lip barely erect and minutely serrate, inner surface with six strong denticles; columellar lip with three or four pustules; siphonal canal moderately long, narrowly open, slightly recurved. *Color:* cream, tinted with pinkish red on the last whorl and outer lip; aperture yellow, denticles and pustules white.

These muricids are uncommon, collected at depths of about 30 m.

M. martinetana occurs from the Red Sea to the Ryukyu Islands (Radwin and D'Attilio, 1976).

Muricodrupa funiculus (Wood, 1828). Fig. 83 I. (Synonyms: *Sistrum triangulatum* Pease, 1868a; *Morula fiscella* (Gmelin, 1791) Edmondson, 1933.) Length, 25 mm; diameter, 15 mm. *Shell:* fusiform-triangular; clathrate; gray. *Spire:* five whorls plus the protoconch; shoulders of the whorls angulated; suture obscure. *Sculpture:* low, rounded axial ribs with narrower interspaces crossed by sharply imbricated spiral threads with narrower channeled interspaces; the axial and spiral sculpture produce a clathrate or "windowed" effect. *Aperture:* narrow, channeled at the suture; outer lip crenulated by sculpture and with five denticles within. *Color:* gray-brown, aperture lavender. Beachworn specimens often have a skeletal appearance.

M. funiculus is a common species in shallow water, occurring under rocks on benches and on fringing reefs. Ostergaard (1939, as *Morula triangulata*) reports the species from Pleistocene fossil deposits on Molokai.

This species occurs throughout the Indo-West Pacific. Radwin (pers. comm.) describes the radula as muricine rather than thaidid.

Pterynotus elongatus (Solander in Lightfoot, 1786). Fig. 83 H. Length, 90 mm; diameter, 40 mm. *Shell:* elongate-fusiform; heavy; with erect hooklike scales and winglike varices; light brown. *Spire:* eight or ten moderately convex whorls distinctly set off from the last whorl; suture channeled. *Sculpture:* smooth or obsoletely ridged and striated, plicate between the varices; three axially oriented varices, the last broad

and winged. *Aperture:* suboval; lip fimbriated; canal elongate, nearly closed. *Color:* light brown. *Animal:* foot and mantle cream, reticulated with light brown (Cross, 1967a).

P. elongatus has only recently (1961) been recorded from the Hawaiian Islands. These muricids are rarely found, occurring at depths of 8 to 20 m hidden among coral blocks and rubble.

This species is distributed from the Red Sea to Japan, northern Australia, and Fiji.

Vitularia miliaris (Gmelin, 1791). Fig. 83 E. (Synonym: *Vitularia sandwicensis* Pease, 1861a.) Length, 34 mm; diameter, 23 mm. *Shell:* pyriform, spire short, last whorl the largest; scabrous; brown with darker brown on the apertural varix. *Spire:* protoconch of one and one-half whorls; teleoconch short, turreted, whorls angular at the periphery, last whorl the largest. *Sculpture:* four or more thin, axial varices fimbriated by rough spiral threads. *Aperture:* ovate; outer lip fimbriated by a varix and denticulate within; siphonal canal narrow and slightly recurved. *Color:* orange-brown with splashes of dark brown on the varices; aperture white.

This species occurs at depths of 30 to 60 m; elsewhere in the Indo-West Pacific *V. miliaris* occurs in shallow water or even exposed on reefs at low tide (Cernohorsky, 1967b).

Additional Records

Fossil shells of *Phyllocoma convoluta* (Broderip, 1833), which is widespread in the Pacific, have been collected from Pleistocene deposits on Oahu, but there are no recent records indicating that this species now lives in Hawaiian waters.

Occasional specimens of *Marchia laqueata* (Sowerby, 1841) and *M. triptera* (Born, 1778) have recently been collected in the Hawaiian Islands.

Family **Thaididae**

This group of muricaceans is given family status here as a matter of convenience rather than of phylogeny. Emerson and Cernohorsky (1973) and Ponder (1973) suggest that the group is not sufficiently distinct anatomically from the Muricidae to warrant family distinction. Thaidid shells, however, lack the prominent spinose processes of other muricids. In general, thaidid shells are of medium size (30 mm in length), rather solid, and conspicuously tuberculate, covered with imbricated spiral threads, or relatively smooth.

The thaidids exhibit a variety of feeding habits (Fig. 84). Among the common intertidal forms in the Hawaiian Islands, *Morula granulata* is a generalist, feeding on a variety of shelled invertebrates such as mollusks and barnacles. Others are more specialized. *Neothais harpa* feeds only on gastropods such as littorines and nerites; *Drupa morum* preys on worms; *Vexilla* spp. feed on sea urchins; and *Drupella elata* preys on living coral.

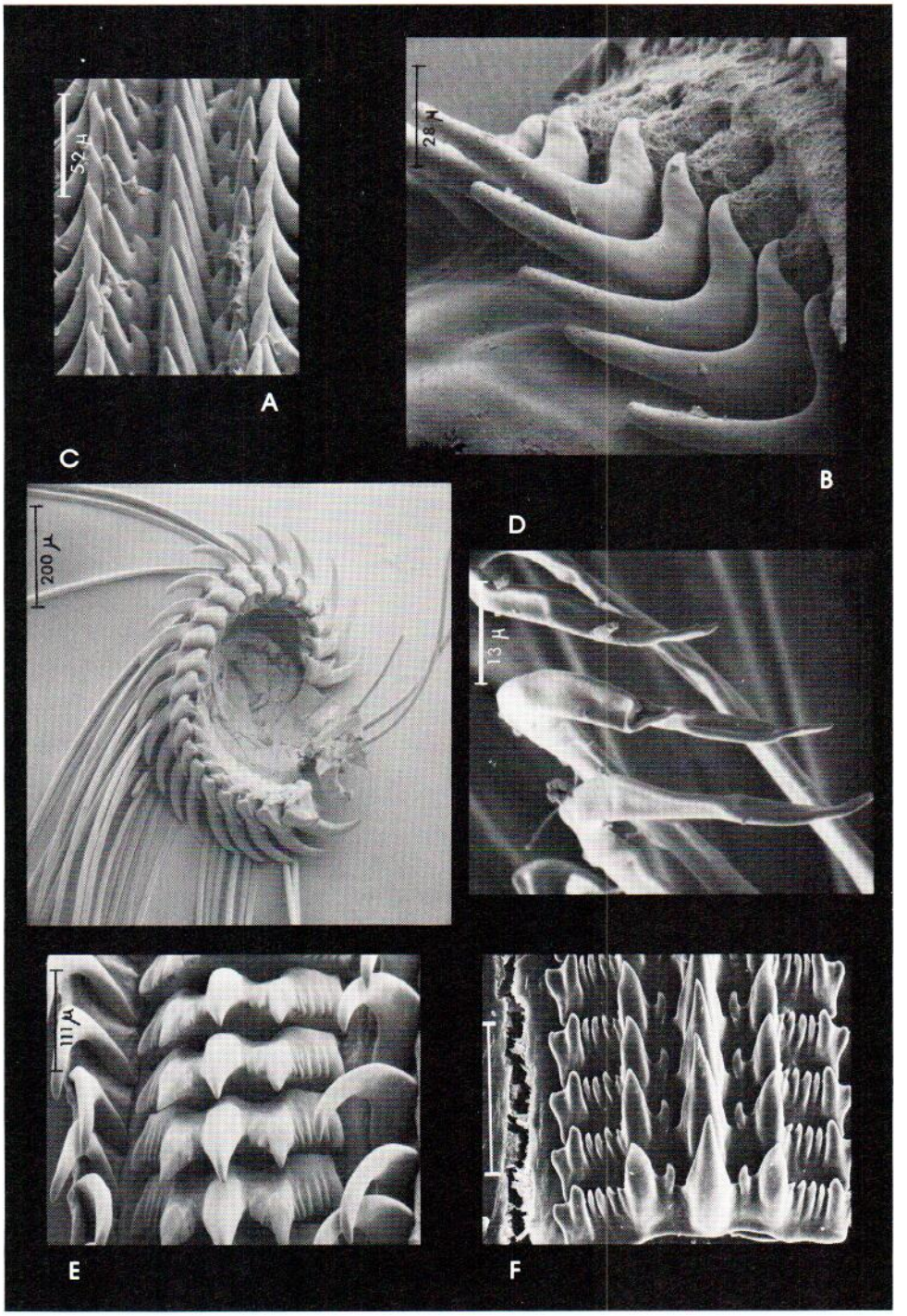


Figure 84.—**Thaididae** radulae. A, B. *Drupa morum*, rows of radular teeth (A) and marginal teeth (B). C, D. *Drupella ochrostoma* rows of radular teeth (C) and tips of marginal teeth (D). E. *Purpura aperta* rows of radular teeth. F. *Neothais harpa* rows of radular teeth. (From H. Rehder.)

The sexes are separate and the egg capsules are deposited on solid substrates. J. B. Taylor (1975) identified 14 species of thaidid veligers in the plankton of Kaneohe Bay, Oahu (Fig. 85); all were four-lobed veliger larvae.

Of the 27 species recorded in the Hawaiian Islands, 18 range throughout the Indo-West Pacific, five are known only from the Pacific basin, and four species appear to be endemic. Fourteen species are common on intertidal shorelines, two are found on the outer edge of fringing reefs, and the others are restricted to depths of several meters.

Drupa (Drupa) morum Röding, 1798. Figs. 84 A, B; 86 D. (Synonym: *Drupa horrida* Tryon, 1880.) Length, 30 mm; diameter, 24 mm. *Shell:* dome-shaped, heavy; with blunt tubercles; white, tubercles black, aperture purple. *Spire:* apex flat, last whorl expanded; suture not visible. *Sculpture:* thick, blunt tubercles with fine spiral striae between. *Aperture:* narrow; outer lip thick, with two grouped series of teeth; operculum dark red with a thick inner border and purpuroid markings. *Color:* white with black tubercles; aperture purple. The shells are often covered with a heavy growth of coralline algae or small vermetids.

These gastropods are common on benches, reefs and basalt shores where there is heavy surf action and on rocky substrates to depths of 15 m. *D. morum* preys on polychaete worms (Bernstein, 1970). It has been reported in Pleistocene fossil deposits on Oahu (Ostergaard, 1928, as *D. horrida*).

This species is well known throughout the Indo-West Pacific, and has also been reported from Clipperton Island (Hertlein, 1937).

Drupa (Drupa) ricina (Linnaeus, 1758). Fig. 86 B. Length, 23 mm; diameter, 18 mm. *Shell:* dome-shaped, solid; tuberculated, and with the outer lip bearing spines; white with black tubercles, aperture sometimes ringed with orange. *Spire:* protoconch of three white whorls; teleoconch low, of about five whorls; suture obscure. *Sculpture:* with spirals of blunt tubercles; outer lip with five long spines interspersed with scalelike ridges. *Aperture:* narrow; outer lip with grouped plaitlike teeth; operculum black, with an eccentric nucleus. *Color:* white, tubercles tipped with black; margin of aperture white with black spots. The shells may be covered with growths of calcareous algae. Occasional shells with an orange ring around the aperture.

These drupes are abundant in the intertidal zone on rocky shores, on sandy shores studded with rocks where they are submerged by wave action and on rocky substrates to depths of 15 m. They feed on worms and mollusks. Shells with an orange ring around the aperture seem to occur only subtidally at depths of 1 to 3 m.

D. ricina is a well-known species throughout the Indo-West Pacific, and is also reported from Clipperton Island (Hertlein, 1937). Shells with an orange ring around the aperture have been distinguished as *D. arachnoides* (Lamarck, 1816). Although Cernohorsky (1969) and Emerson and Cernohorsky (1973) do not recognize the orange-ringed shells as representing a separate species, in the Hawaiian Islands shells with the orange ring are found only subtidally and are characterized by more prominent and thinner spines than those of the intertidal *D. ricina*.

Drupa (Drupina) grossularia (Röding, 1798). Fig. 86 A. (Synonym: *Purpura digitata* Lesson, 1842a.) Length, 22 mm; diameter, 18 mm. *Shell:* dome-shaped, the

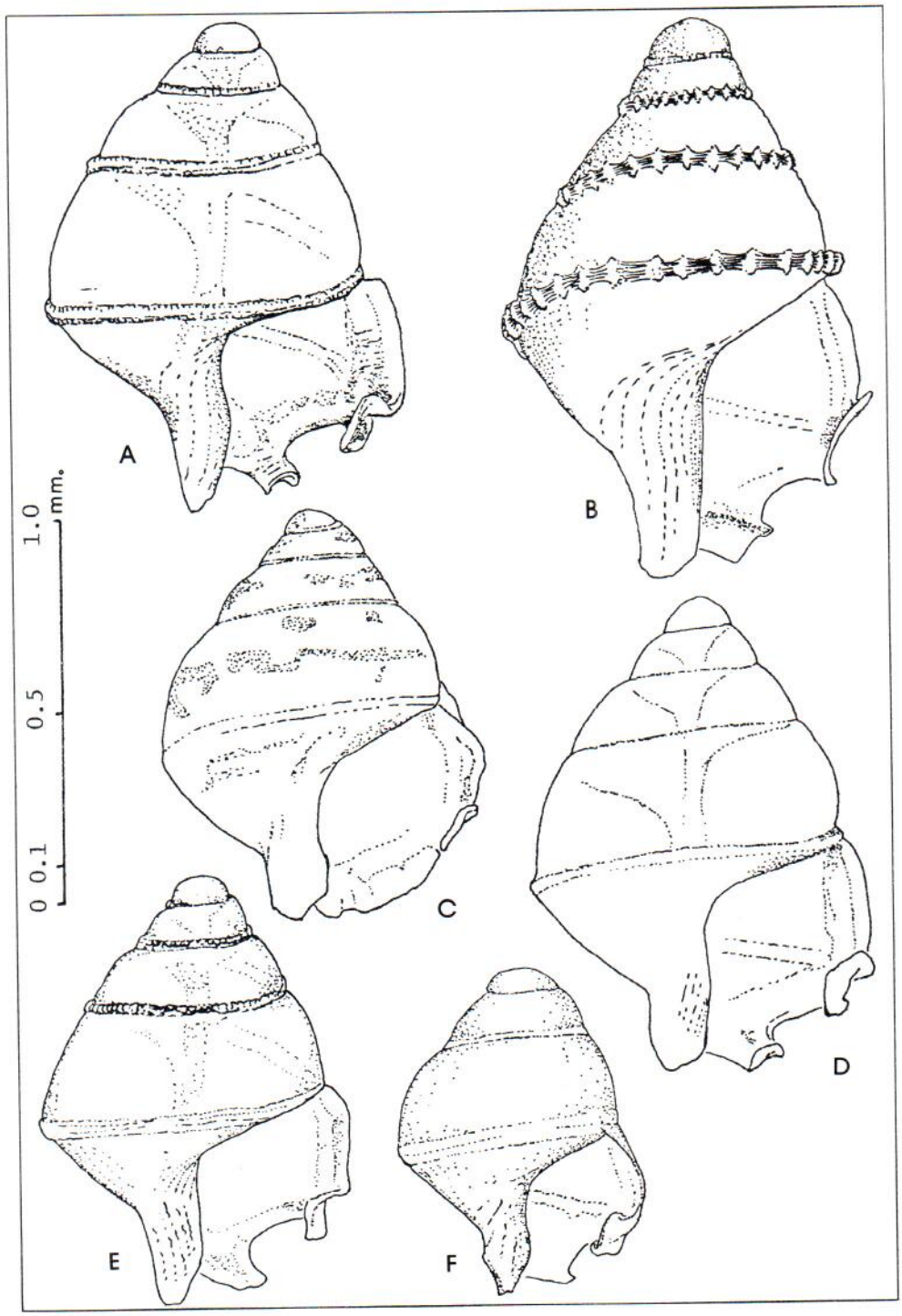


Figure 85.—Premetamorphic protoconchs of **Thaididae.** A. *Drupa ricina*. B. *Vexilla fusconigra*. C. *Pinaxia versicolor*. D. *Drupella cornus*. E. *Maculotriton bracteatus*. F. *Morula granulata*. (From J. B. Taylor, 1975.)

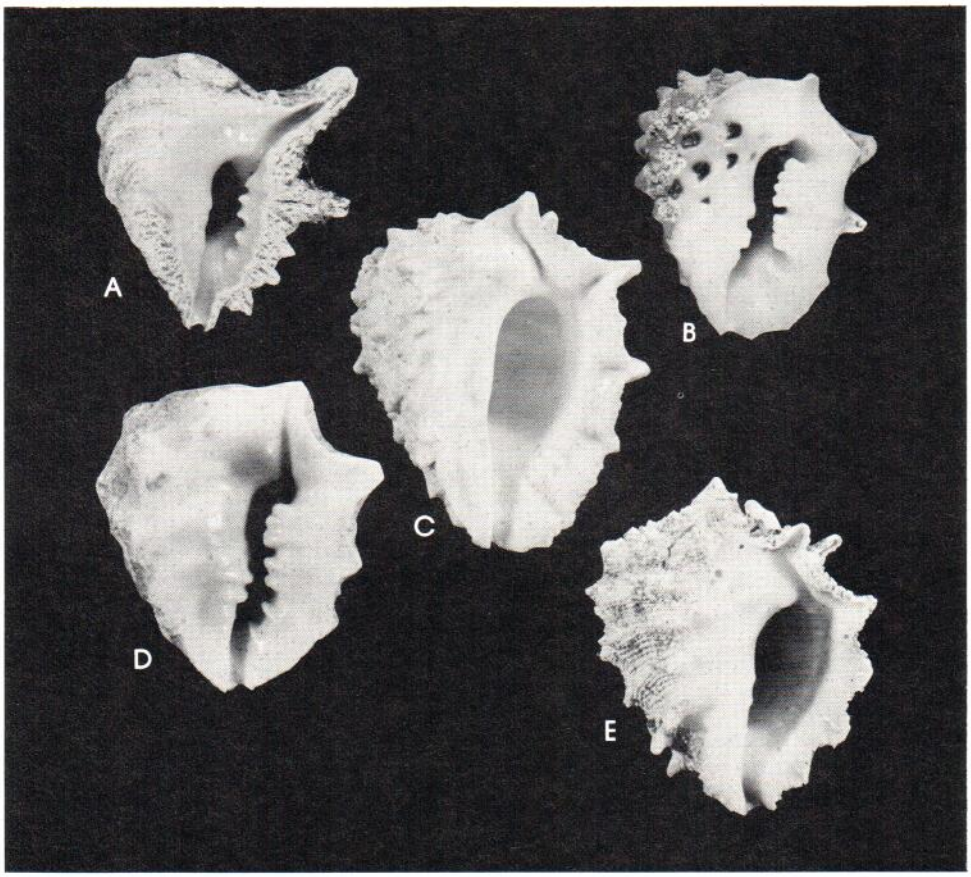


Figure 86.—**Thaididae.** A. *Drupa grossularia,* length 22 mm. B. *D. ricina,* length 23 mm. C. *Purpura aperta,* length 47 mm. D. *Drupa morum,* length 30 mm. E. *D. rubusidaeus,* length 48 mm.

labial lip extended by strong digitations; with spiral cords; white, aperture orange-yellow. *Spire:* low, about four whorls; suture obscure. *Sculpture:* low spiral cords with scabrous spiral threads between. *Aperture:* ovate; outer lip flared with five digitate processes; columella heavily callused and plicate. *Color:* cream or white; aperture orange-yellow. Shell usually encrusted with coralline algae.

Specimens of *D. grossularia* are rarely reported from the windward islands, but are abundant in the leeward islands on the seaward reef flats of Laysan and Midway.

This species ranges from the Cocos-Keeling Islands (Maes, 1967) through the Pacific to both Micronesia and Polynesia.

Drupa (Ricinella) rubusidaeus Röding, 1798. Fig. 86 E. (Synonyms: *Ricinula hystrix* Linnaeus, Tryon, 1880; *Drupa speciosa* Dunker, Edmondson, 1933.) Length, 48 mm; diameter, 47 mm. *Shell:* dome-shaped; with spinose nodules; white, aperture orange-pink. *Spire:* short, last whorl the largest; suture indistinct. *Sculpture:* four to six spirals of blunt nodules on the last whorl, earlier whorls with a single row; fine

imbricated spiral threads between the nodules. *Aperture:* ovate; labial lip with seven to nine denticles which may extend into the aperture; columella with folds anteriorly, edge of columellar callus occasionally denticulate. *Color:* cream to yellow, aperture edged with yellow becoming orange-pink internally, columella dark, flecked with yellow. Shell often encrusted with coralline algae.

These drupes are found subtidally at depths of 1 to 10 m.

D. rubusidaeus occurs throughout the Indo-West Pacific.

Drupella elata Blainville, 1832. Fig. 87 A. (Synonym: *Drupa ochrostoma* (Blainville) var. *spectrum* (Reeve), Tinker, 1958.) Length, 64 mm; diameter, 39 mm. *Shell:* biconic, spire high; with projecting nodules; white, aperture yellow. *Spire:* projecting, acuminate; suture shallow. *Sculpture:* eight axial ribs on the last whorl, with two rows of solid, prominent tubercles peripherally on the last whorl and a single spiral of tubercles on the other whorls; spiral sculpture of fine spiral striae. *Aperture:* ovate; outer lip slightly thickened, with six denticles; columella raised, forming a shield and obsolete plaits; siphonal fasciole moderately developed. *Color:* creamy white, aperture yellow. The shell is often covered with a thick, calcareous deposit.

These thaidids occur at the outer edge of fringing reefs and on basalt substrates to depths of about 3 m on Hawaii. Cernohorsky (1969) reports that this species is sexually dimorphic, with the males smaller than females and with more bulbous shells ornamented with blunt nodules rather than pointed tubercles. In Hawaii *D. elata* feeds on the flesh of madreporarian corals, particularly *Porites compressa* Vaughn (Fankboner, 1970, as *D. cornus*). Feeding involves "spitting" a proteolytic saliva on the tissues followed by rasping and sucking up the partially digested flesh (Fankboner, 1970).

D. elata occurs throughout the Indo-West Pacific.

Drupella ochrostoma (Blainville, 1832). Figs. 84 C, D; 87 B. Length, 15 mm; diameter, 10 mm. *Shell:* biconic; axially ribbed and encircled by nodules and fimbriated spiral cords; yellow-white with an orange aperture. *Spire:* protoconch of three and one-half smooth, bulbous, white whorls; teleoconch of four or five whorls; suture impressed but obscure. *Sculpture:* sharp, oblique axial ribs crossed by fimbriated spiral cords forming sharp nodules at the junctions. *Aperture:* ovate; outer lip thick, lirate within; siphonal fasciole well developed. *Color:* yellow-white, occasionally speckled with brown; aperture orange.

These snails are ubiquitous, abundant under rocks and coral rubble in tide pools, in shallow waters shoreward of fringing reefs and to depths of 100 m. They feed by drilling their prey, which includes *Epitonium* and vermetids in the laboratory.

D. ochrostoma was described from New Ireland and has been recorded from numerous localities in the Indo-West Pacific. Cernohorsky's (1976b) note, based on the study of radular structure, that Blainville's *Purpura ochrostoma* is a *Cronia,* refers to shells other than those of the Blainville species. The Hawaiian shells have been compared with the type of *Purpura ochrostoma* in Paris and are an exact match and the radula is clearly that of *Drupella* (Fig. 84 C, D). Cernohorsky (1976b) figures a shell from Rabaul, New Guinea, and the syntypes of *Ricinula cavernosa* Reeve, 1846, all of which differ from the Blainville shells with brown blotches and corded rather sharp axial spirals.

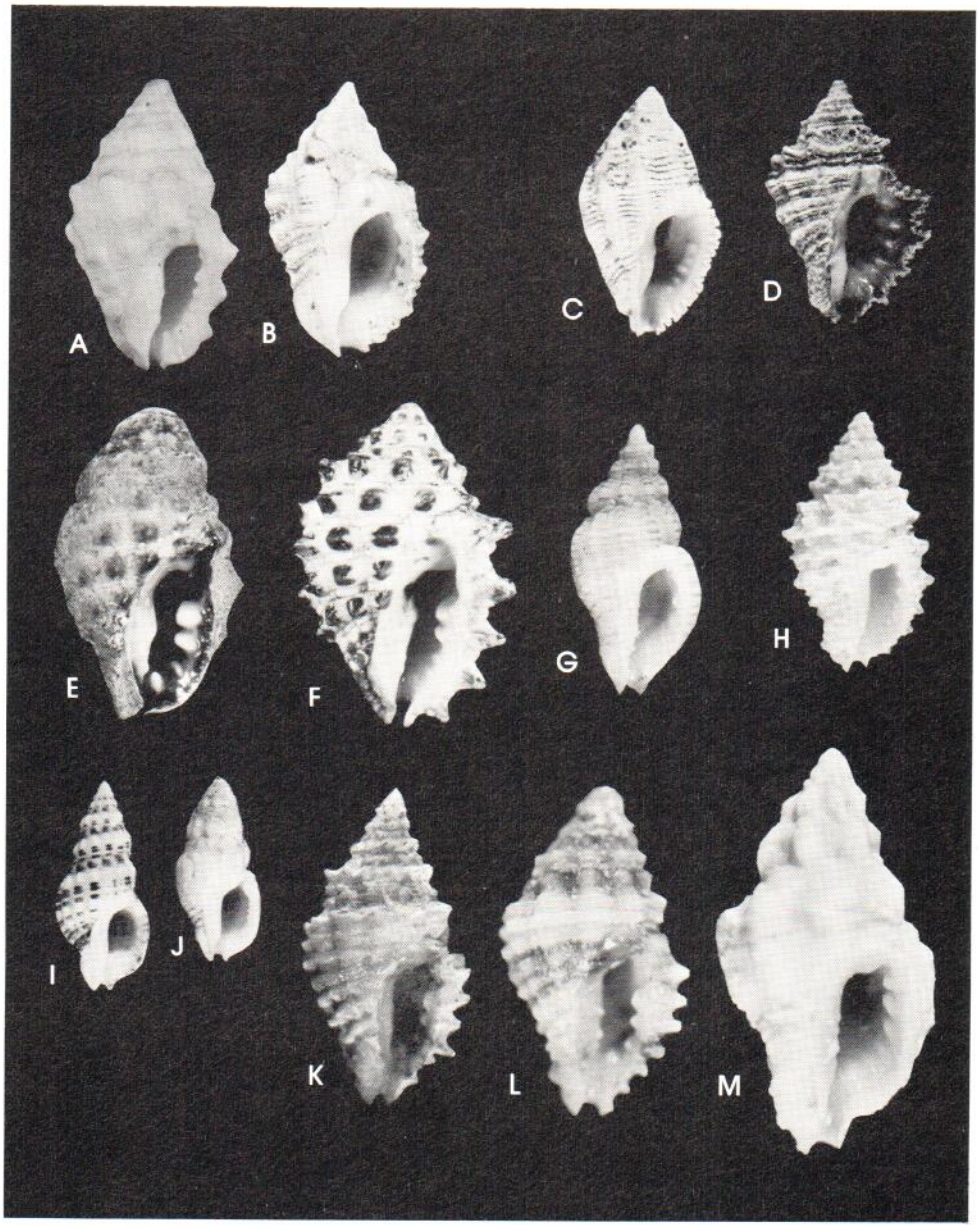


Figure 87.—**Thaididae.** A. *Drupella elata*, length 64 mm. B. *D. ochrostoma*, length 18 mm. C. *Morula dumosa*, length 15 mm. D. *M. foliacea*, length 24 mm. E. *M. granulata*, length 21 mm. F. *M. uva*, length 15 mm. G. *M. vexilla*, length 11 mm. H. *M. spinosa*, length 20 mm. I, J. *Maculotriton bracteatus* (two color forms), length 17 mm. K. *Morula benedictus*, length 9 mm. L. *M. funiculata*, length 7 mm. M. *M. darrosensis*, length 9 mm.

Maculotriton bracteatus (Hinds, 1844). Fig. 87 I, J. (Synonyms: *Maculotriton digitalis* Reeve, Demond, 1957; *Maculotriton serrialis longus* Pilsbry and Vanatta, Tinker, 1958.) Length, 17 mm; diameter, 7 mm. *Shell:* fusiform; with evenly spaced, low axial ribs and close-set spiral threads; white or white spirally banded with black. *Spire:* protoconch conic, smooth, of about three whorls; teleoconch of five or six moderately convex whorls; suture impressed. *Sculpture:* ten or twelve rounded axial ribs and varices most prominent near the periphery of the whorls; spiral sculpture of close-set threads. *Aperture:* narrow, with a heavy varix behind the outer lip and six to seven lirations within; canal short and recurved; operculum purpuroid, dark red, with a heavy ridge anteriorly. *Color:* variable — cream, yellow, or white or white with spirals of black threads or dashes. *Animal:* apple green spotted with white and with a black smudge on the side of the foot and on the proboscis.

Specimens are common in tide pools and under rocks in shallow waters shoreward of fringing reefs on Maui, Oahu, and Kauai, but are rare on Hawaii. There appears to be no correlation between color pattern and either sex or environment, although black and white shells are twice as numerous as white shells. These thaidids feed on other mollusks by drilling.

This species is comparatively common in the Indo-West Pacific, from the eastern coast of Australia, Lord Howe Island, and New Caledonia, Kermadec Islands, and southern Japan (Ponder, 1972b).

Morula benedictus (Melvill and Standen, 1895). Fig. 87 K. Length, 8.5 mm; diameter, 4 mm. *Shell:* fusiform; with sharply angulated and noduled axial ribs and crisp spiral threads; light brown. *Spire:* protoconch of two and one-half conical, inflated whorls; teleoconch of four whorls, concave below the suture and angulated at the periphery; suture barely impressed. *Sculpture:* sharp axial ribs crossed by crisp spiral cords, the junctions of ribs and cords forming short, erect spines at the periphery of the last whorl and just above the suture on the apical whorls; interspaces between spiral cords with fine axial and spiral threads; last whorl with eight axial ribs and five spiral cords. *Aperture:* ovate, narrow, contracting to an open, distinctly recurved siphonal canal; outer lip erect, thickened externally by a varix, with six short, spaced denticles internally; columella apparently smooth. *Color:* cream suffused with light and darker brown.

These thaidids are common at depths of about 10 m.

M. benedictus was described from Lifu, Loyalty Islands.

Morula darrosensis (Smith, 1884). Fig. 87 M. Length, 10 mm; diameter, 5 mm. *Shell:* fusiform, ovate; with angular axial ribs noduled by spiral cords; white with spirals of dark brown on the last whorl; aperture yellow. *Spire:* protoconch of three and one-half conical whorls; teleoconch of about four whorls, concave at the shoulder and angulated near the middle; suture impressed. *Sculpture:* thick, protruding axial ribs noduled where they are crossed by spiral cords and with finer spiral threads between the spiral cords; last whorl with eight or nine axial ribs, five or six spiral cords. *Aperture:* ovate, contracted into a short, open, oblique siphonal canal; outer lip nearly straight, thickened by a varix and with six internal lirae; columella straight with two plications below the middle. *Color:* white, spotted on and between the spiral cords with dark brown; aperture deep yellow.

Shells are rather uncommon, dredged at depths of about 50 m.

M. darrosensis was described from shells dredged at depths of about 44 m in the Amirante Isles, Indian Ocean.

Morula dumosa (Conrad, 1837). Fig. 87 C. (Synonym: *Morula porphyrostoma* Reeve, Mant, 1923.) Length, 15 mm; diameter, 8 mm. *Shell:* pyriform-biconic; axially ribbed and sharply spirally striated; gray, aperture bright purple. *Spire:* protoconch of two dark brown whorls; teleoconch of five convex whorls; suture impressed. *Sculpture:* seven or eight narrow axial ribs separated by wider interspaces; spiral sculpture of sharp striae. *Aperture:* subovate; outer lip and columella with three or four teeth. *Color:* gray, aperture bright purple. *Animal:* exposed portions sooty white smudged with black; tentacles white.

Specimens are common under rocks in the shallow waters shoreward of fringing reefs among the windward islands and abundant on the reef flats at French Frigate Shoals and Lisiansky. In the laboratory *M. dumosa* feeds by drilling its prey, which includes vermetids and *Ostrea* spp.

M. dumosa was described from the Hawaiian Islands. Pease (1868a) erred in suggesting that *M. dumosa* is a synonym of *M. porphyrostoma* (Reeve, 1846), described from the Marquesas. Recent Hawaiian shells match Conrad's figure and description almost exactly and are distinguished from those of *M. porphyrostoma* by their scalar rather than spinose sculpture and pyriform rather than ovate shape.

Morula foliacea (Conrad, 1837). Fig. 87 D. (Synonyms: *Cuma muricina* Blainville, Pease, 1868a; *Morula brunneolabrum* Dall, 1923.) Length, 24 mm; diameter, 17 mm. *Shell:* pyriform, peripherally angulated; spinose and imbricate; aperture and lips chocolate brown. *Spire:* protoconch of three white or pale straw-colored whorls; teleoconch projecting; last whorl somewhat angulated; suture obscure. *Sculpture:* low axial ribs made spinose by the spiral sculpture of imbricated threads, the interspaces subequal in diameter to the ribs. *Aperture:* ovate; outer lip fimbriated by the external sculpture and denticulate within; columella smooth; siphonal fasciole barely developed. *Color:* pale brown, the spiral threads darker; aperture chocolate. *Animal:* white, mottled with red-brown.

These animals are common under rocks on benches and in shallow water shoreward of fringing reefs, and are often found with the bivalve *Brachidontes*. They spawn in January and February, producing small yellow and white egg capsules that are clustered on the undersurfaces of rocks.

M. foliacea was described from the Hawaiian Islands. The shells are wider than are those of *M. spinosa* and the denticles are paired rather than evenly spaced.

Morula funiculata (Reeve, 1846). Fig. 87 L. (Synonyms: *Engina monilifera* Pease, 1860; *E. iodosia* Duclos, Melvill and Standen, 1895.) Length, 7 mm; diameter, 4 mm. *Shell:* biconic; with coarse axial ribs granuled by spiral threads; white with a spiral band of purple-brown and with a single row of yellow granules below the suture. *Spire:* protoconch of three and one-half conical white whorls; teleoconch of six or seven whorls; whorls convexly angulated; suture faintly defined. *Sculpture:* coarse axial ribs, the interspaces of equal diameter, crossed by granular spiral threads of

lesser diameter than the ribs. *Aperture:* ovate, narrow; outer lip nearly straight, thick, with four internal denticles and three smaller denticles near the base; columella straight, with two plications. *Color:* white with a broad, interrupted spiral band of purple-brown on the last whorl and a narrower spiral at the sutural band margin; suture bordered by a single row of yellow granules. *Animal:* exposed parts cream tinted with green and flecked with opaque white and with a dark brown splash dorsally on the foot.

Specimens of *M. funiculata* are found on the undersurfaces of rocks in tide pools and shallow water subject to considerable wave action, under rocks on benches and in beds of the sea anemones *Zoanthus* and *Palythoa*. The shells are often covered with algal debris. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

This species is widely distributed in the Indo-West Pacific, recorded from Mauritius and the Solomon Islands (Viader, 1937; Smith, 1876, as *Engina*). Cernohorsky (1975a) noted the lectotype of Pease's *Engina monilifera* was conspecific with the holotype of *Ricinula echinata* Reeve= *M. funiculata*.

Morula granulata (Duclos, 1832). Fig. 87 E. (Synonyms: *Morula nodus* St. Vincent, Tinker, 1952; *M. tuberculata* Blainville, Edmondson, 1933.) Length, 21 mm; diameter, 14 mm. *Shell:* fusiform, solid; gray-black with darker tubercles. *Spire:* protoconch of three glistening smooth, light brown whorls with a darker brown band peripherally on the abapical whorl; teleoconch of five whorls; suture obscure. *Sculpture:* ten axial ribs and six spiral ribs forming tubercles at the junctions. *Aperture:* narrow; outer lip with four single teeth; columella obscurely plaited. *Color:* gray-black with dark tubercles; parietal area white; surface of shell often covered with encrusting calcareous algae.

M. granulata is very common in the intertidal zone on hard substrates where there is strong wave action. These gastropods feed by drilling their prey, usually other mollusks such as vermetids and oysters (A. C. Miller, 1970); they also exhibit carrion-type feeding when dead mollusks are available (Wu, 1965).

This species is distributed throughout the Indo-West Pacific.

Morula spinosa (H. and A. Adams, 1853). Fig. 87 H. (Synonyms: *Morula fuscoimbricata* Sowerby, 1915; *Drupa walkerae* Pilsbry and Bryan, 1918; *Morula elata* Blainville, Morris, 1966.) Length, 20 mm; diameter, 10 mm. *Shell:* biconic; axially arranged spines and imbricated scales; cream, spines dark brown. *Spire:* apical whorls of teleoconch projecting; suture shallow. *Sculpture:* eight to ten oblique rounded axial ribs rendered spinose where they are crossed by spiral cords and with finer imbricate or scaly spiral threads between the cords; five major cords on the last whorl and three finer threads between. *Aperture:* narrowly ovate, longer than spire; outer lip thin with six or seven denticles within which extend into the aperture; columella straight, with three plaits, glazed. *Color:* cream, spines and cords dark brown.

These thaidids are uncommon in the windward islands but abundant at Pearl and Hermes Reef, French Frigate Shoals, and Laysan.

M. spinosa is moderately common in the Pacific (Cernohorsky, 1972a). *M. fuscoimbricata* was described from a subfossil shell dredged from Honolulu Harbor,

and all shells referable to Sowerby's *M. fuscoimbricata* and Pilsbry and Bryan's *Drupa walkerae* are from the same dredge area. Worn shells are distinguished by their white background, brown nodules, and blunt spines.

Morula uva (Röding, 1798). Fig. 87 F. (Synonym: *Morula nodus* (St. Vincent) Cooke, 1919.) Length, 15 mm; diameter, 11 mm. *Shell:* biconic, solid; white with black tubercles, aperture purple. *Spire:* protoconch of four smooth, convex whorls with the suture barely visible, brown with lighter banding; teleoconch of five whorls; suture obscure. *Sculpture:* axially arranged blunt tubercles on spiral cords, the cords separated by a single spiral thread. *Aperture:* ovate; outer lip crenulate, with two large and two smaller teeth; columella with two to three folds. *Color:* white with black tubercles; aperture purple. *Animal:* white smudged with black; tentacles and sole of foot white, siphon black, edged with white.

M. uva is found on basalt shorelines and reefs, in protected areas and where there is heavy surf action. These thaidids feed primarily on vermetids (A. C. Miller, 1970). Ostergaard (1928) reported this species in Pleistocene fossil deposits on Oahu.

M. uva occurs throughout the Indo-West Pacific.

Morula vexilla (Kuroda, 1953). Fig. 87 G. Length, 11 mm; diameter, 5 mm. *Shell:* biconic, spire projecting; with strong axial ribs and sharp spiral keels; cream, the axial ribs brown at their junctions with the spiral keels. *Spire:* protoconch of three smooth, white whorls; teleoconch of four whorls, the last the largest; suture deep and distinct. *Sculpture:* prominent axial ribs with interspaces of slightly greater diameter, the ribs made nodular by sharp spiral keels which cross the ribs and intercostal spaces; a single row of prominent tubercles occurs below the periphery of the last whorl. *Aperture:* oval, outer lip thin with four or five denticles within; columella straight. *Color:* cream, the axial ribs chestnut brown where they are crossed by the spiral keels.

These thaidids occur at depths of 50 m off Oahu.

M. vexilla was described from Tosa Bay, Shikoku, Japan, and has been reported from depths of 100 to 200 m (Habe, 1964).

Nassa serta (Bruguière, 1789). Fig. 88 A. (Synonym: *Nassa francolinus* (Bruguière) Tinker, 1958.) Length, 39 mm; diameter, 18 mm. *Shell:* pyriform, smooth; brown flashed with pink. *Spire:* projecting, last whorl inflated; suture obscure. *Sculpture:* microscopic spiral striae only, becoming slightly grooved at the base. *Aperture:* ovate; outer lip flaring; columella straight, with a twisted fasciole and a nodule beneath the suture. *Color:* chestnut brown spiralled or flashed with pink-brown.

These gastropods are fairly common, occurring under rocks in shallow water and occasionally on the reef where they may be exposed to heavy surf.

N. serta is found in the Pacific Ocean and at Cocos-Keeling Islands, while *N. francolina* (Bruguière, 1789) occurs in the Indian Ocean (Orr, 1966).

Neothais harpa (Conrad, 1837). Figs. 6 C; 84 F; 88 B. Length, 28 mm; diameter, 17 mm. *Shell:* fusiform; cancellated; gray. *Spire:* six convex whorls; suture impressed. *Sculpture:* axial and spiral cords crossing, producing a cancellated appearance. *Aperture:* ovate; outer lip thin, fimbriated; operculum dark red. *Color:* gray; aperture

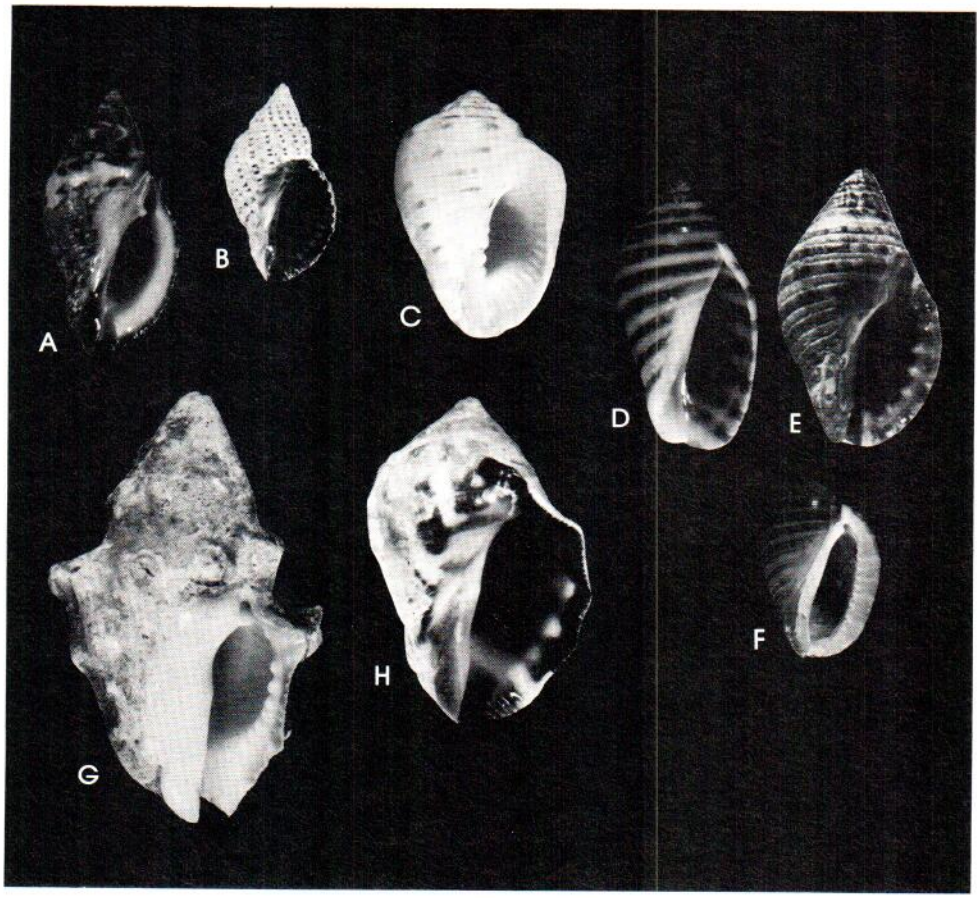


Figure 88.—**Thaididae.** A. *Nassa serta*, length 39 mm. B. *Neothais harpa*, length 28 mm. C. *Pinaxia versicolor*, length 15 mm. D. *Vexilla vexillum*, length 20 mm. E. *V. fusconigra*, length 10 mm. F. *V. lineata*, length 12 mm. G. *Thais armigera*, length 64 mm. H. *Thais intermedia*, length 42 mm.

lighter in color. *Animal:* exposed parts cream, tentacles sooty at the base, red brown in the middle and tipped with yellow; siphon and upper part of foot sooty.

N. harpa is found in the high-splash zone of the shoreline with *Littorina pintado*, *Nodilittorina picta*, and *Nerita picea*. The thaidids feed on nerites and littorines by drilling.

This species was erroneously described from the west coast of the Americas by Conrad from shells collected by Thomas Nuttall during his visit to the Hawaiian Islands in 1834-35. *N. harpa* is endemic to the Hawaiian Islands.

Pinaxia versicolor (Gray, 1839). Fig. 88 C. Length, 15 mm; diameter, 11 mm. *Shell:* triangular, the last whorl the largest; cream-orange with spirals of brown dashes. *Spire:* apex short and blunt; last whorl abruptly angled; suture channeled. *Sculpture:* microscopic spiral striae. *Aperture:* triangular; outer lip thin; operculum muricoid, thin, subquadrate, the inner side finely radiately striate. *Color:* cream-orange splashed with

brown and orange and spirally banded with dark brown dashes; periostracum thick and fibrous.

These thaidids are rarely encountered, in shallow water and to depths of 80 m. They feed by drilling bivalves such as *Brachidontes* in the laboratory.

This species is well known throughout the Indo-West Pacific.

Purpura aperta (Blainville, 1832). Figs. 84 E; 86 C. (Synonym: *Purpura macrostoma* Conrad, 1837.) Length, 37 mm; diameter, 29 mm. *Shell:* dome-shaped, solid; noduled and spirally striated; cream colored. *Spire:* apex flattened; last whorl much enlarged; suture obscure. *Sculpture:* sharply pointed nodules which form axial ribs, and spiral threads. *Aperture:* wide; outer lip flaring, denticulate and ornamented with external sculpture; operculum large, dark red, and typically purpuroid. *Color:* white, aperture tinged with yellow; usually densely coated with coralline algae.

These mollusks occur along exposed shoreline in areas which receive heavy surf, where they feed on opihi (*Cellana* spp.). The animals were eaten by the Hawaiians.

Pease (1868a) and Cernohorsky (1972a) suggest that *P. aperta* is endemic to the Hawaiian Islands, but shells which appear to represent the same species from Oshima, Japan, are in the Dautzenberg Collection in Belgium, and have also been collected at Enewetak, Marshall Islands. Conrad's (1837) Santa Barbara, California, locality for *P. macrostoma* was incorrect; the specimens were Hawaiian, collected by Thomas Nuttall (Keen, 1966).

Thais armigera (Link, 1807). Fig. 88 G. (Synonym: *Purpura affinis* Reeve, Tinker, 1958.) Length, 64 mm; diameter, 39 mm. *Shell:* biconic, spire projecting; massive, two rows of projecting nodules on the last whorl; white, aperture yellow. *Spire:* projecting and acuminate; suture shallow. *Sculpture:* eight axial ribs with two rows of prominent tubercles encircling the last whorl, a single spiral of tubercles on the other whorls; spiral sculpture of fine striae. *Aperture:* ovate; outer lip slightly thickened, with six denticles; columella with a single obsolete plait; siphonal fasciole moderately developed. *Color:* white, aperture yellow. Shell often covered with a thick calcareous deposit.

These gastropods occur at the outer edge of fringing reefs and on subtidal lava shoulders exposed to heavy wave action.

T. armigera ranges throughout the Indo-West Pacific.

Thais intermedia (Kiener, 1836). Fig. 88 H. Length, 42 mm; diameter, 29 mm. *Shell:* ovate, solid; with prominent white nodules on a dark gray or black background. *Spire:* four whorls; suture impressed. *Sculpture:* low blunt tubercles axially arranged and fine spiral threads. *Aperture:* outer lip thickened; lirate within. *Color:* gray-white with white nodules and axially arranged splashes of black; aperture white; columella gray-brown.

These mollusks are occasionally collected from the outer edges of reefs and on basalt benches where there is heavy surf. They feed on opihi (*Cellana* spp.)

T. intermedia has been reported from various localities in the Indo-West Pacific.

Vexilla fusconigra Pease, 1860. Fig. 88 E. (Synonym: *Vexilla nigro-fusca* A. Adams, 1861.) Length, 10 mm; diameter, 6 mm. *Shell:* abbreviately fusiform; with

spiral granular threads; dark brown. *Spire:* protoconch of three smooth, brown whorls; teleoconch of six convex whorls, the last whorl the largest; suture impressed. *Sculpture:* closely spaced spiral granular threads separated by impressed grooves; with some fine axial striae and wrinkles. *Aperture:* oblong-ovate, outer lip thick and dilated, with six internal teeth; columella straight, flat, and glazed; a shallow, almost vertical sinus at the junction of the body whorl and outer lip. *Color:* dark brown to black, the spiral grooves lighter; lip purple brown, teeth white or blue.

The habits of *V. fusconigra* are different from those of the other species of *Vexilla*. These animals are found under rocks, usually where there is a slight admixture of freshwater and nearly always in company with *Planaxis*.

V. fusconigra has been described from at least two other localities in the Indo-West Pacific, from Réunion (as *V. leucostoma* Deshayes, 1863) and Okinawa (as *Planaxis cingulata* Gould, 1861, non A. Adams, 1851).

Vexilla lineata A. Adams, 1853c. Fig. 88 F. (Synonyms: *Purpura striatella* Garrett, 1857; *Vexilla thaanumi* Pilsbry, 1921.) Length, 12 mm; diameter, 7 mm. *Shell:* oval; spirally striated; dark brown with spiral threads of yellow. *Spire:* apical whorls short, blunt; suture obscure. *Sculpture:* spirally striate. *Aperture:* elongate, flaring basally and with a small sulcus apically; outer lip strongly denticulate; columella straight. *Color:* dark brown, with four or five yellow spiral threads; aperture brown or gray.

These gastropods are uncommon, found clinging to the oral surface of the shingle urchin *Colobocentrotus* on which they presumably feed.

V. lineata was described from the Philippines and also occurs in southern Japan and the Marshall Islands.

These shells may be distinguished from those of *V. vexillum* by their smaller size, wider spire, spirally striated surface, narrow light colored lines on a dark background, and dark aperture.

Vexilla vexillum (Gmelin, 1791). Figs. 88 D; 89. (Synonym: *Vexilla taeniata* Powis, Edmondson, 1933.) Length, 20 mm; diameter, 11 mm. *Shell:* ovate-oblong, last whorl the largest; smooth; with brown and yellow spiral bands of the same size. *Spire:* apical whorls short, expanding rapidly into the large last whorl; suture obscure. *Sculpture:* microscopic, fine spiral striae. *Aperture:* elongate, flaring; outer lip denticulate; columella straight, flatly excavated, especially near the anterior canal. *Color:* yellow with six to eight equally spaced spiral bands of brown; aperture white, external banding showing through.

The animals are found on the sea urchins *Echinometra* and *Colobocentrotus* on which they feed by protruding a long proboscis beneath the spines of the echinoderms (Fig. 89).

V. vexillum occurs throughout the Indo-West Pacific.

Additional Records

Two species of thaidids are known from single records in the Hawaiian Islands. One specimen of *Drupa elegans* (Broderip and Sowerby, 1829) was collected at Pearl

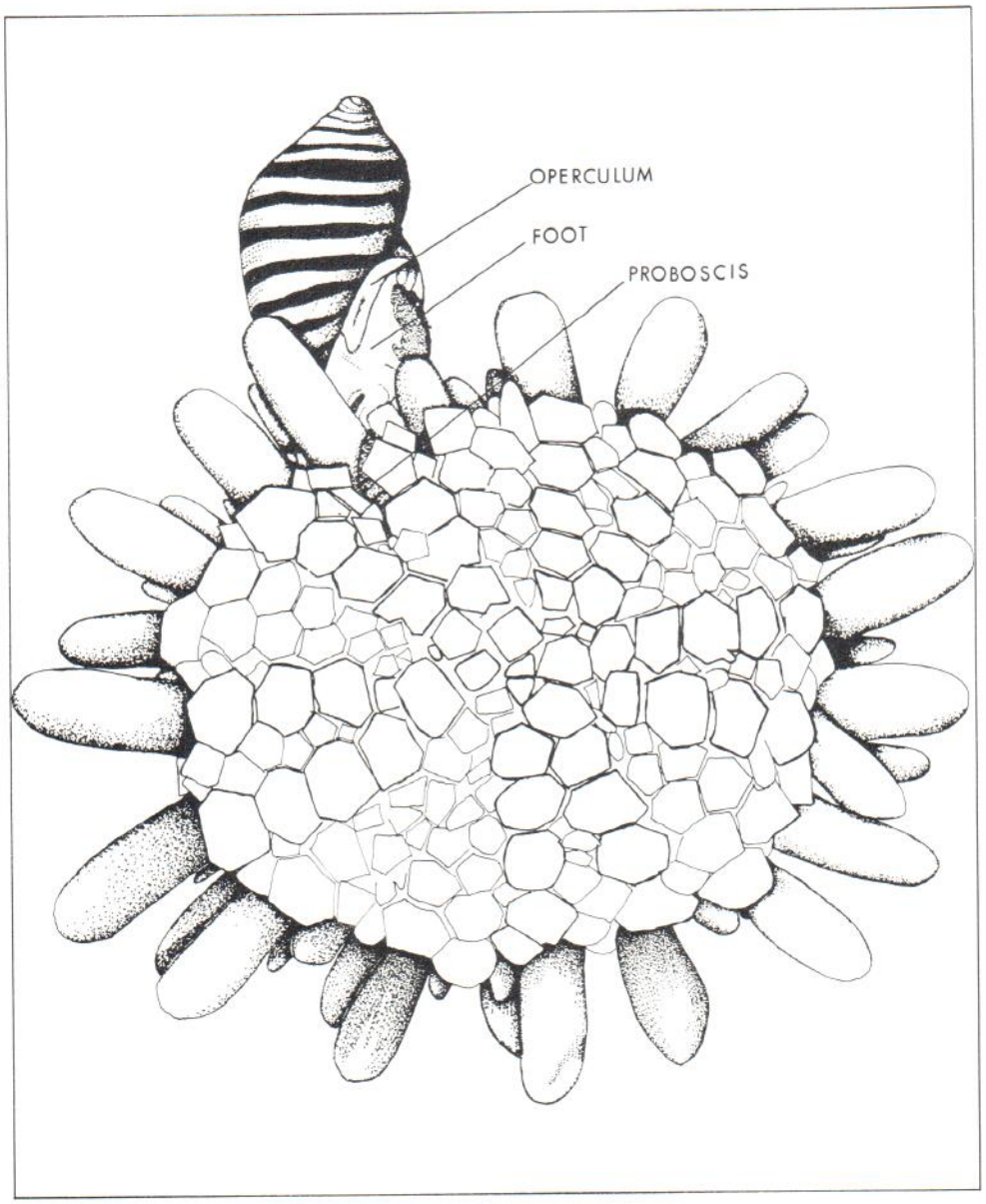


Figure 89.—*Vexilla vexillum* feeding on the helmet urchin, *Colobocentrotus atratus*. (By R. Kawamoto.)

and Hermes Reef by the *Tanager* Expedition in 1926. A single specimen of *Thais echinulata* (Lamarck, 1822) is reported from a depth of 3 m off Oahu (Weaver, pers. comm.). *Purpura fuscata* Forbes, 1852, was erroneously described from the Hawaiian Islands.

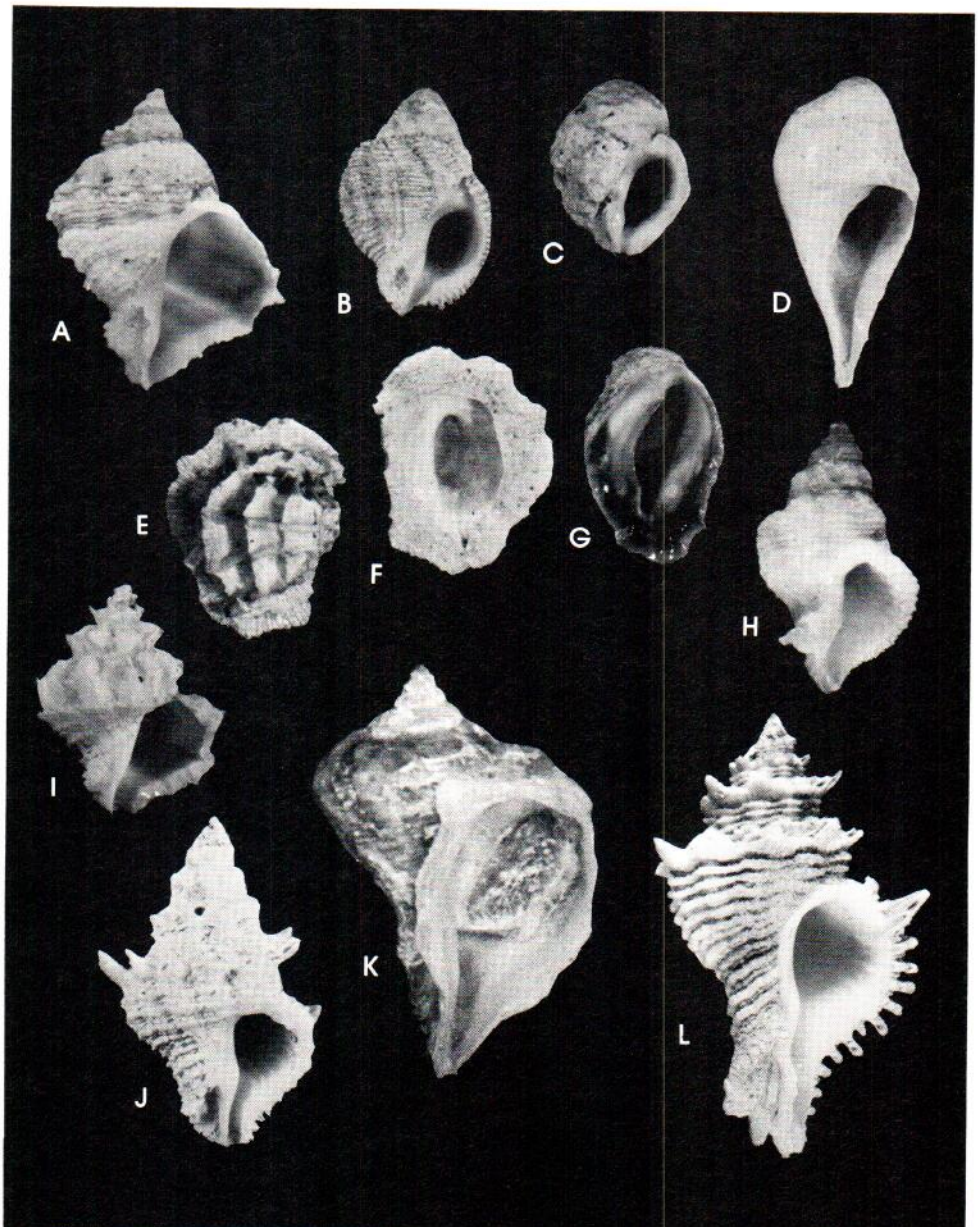


Figure 90.—**Coralliophilidae.** A. *Coralliophila d'orbignyana*, length 26 mm. B. *C. erosa*, length 30 mm. C. *C. violacea*, length 36 mm. D. *Magilopsis lamarckii*, length 17 mm. E, F. *Coralliobia fimbriata*, length 20 mm. G. *Quoyula madreporarum*, length 30 mm. H. *Coralliophila nodosa*, length 20 mm. I. *Latiaxis cuspidifera*, length 23 mm. J. *L. tosanus*, length 29 mm. K. *Rhizochilus antipathicus*, length 25 mm. L. *Latiaxis japonicus*, length 41 mm.

Family **Coralliophilidae**

The members of this family live in close association with corals and exhibit a variety of shell forms. The shells of *Coralliophila* resemble those of muricids, those of *Quoyula* are limpetlike, and the shells of *Magilopsis* are embedded in coral and vermiform. While the coralliophilids merely cling to coral, moving about freely, *Quoyula* and *Magilopsis* are permanently attached to the substrate. Most coralliophilid shells are white except for the brightly colored aperture. Sculpture when it is present consists of rows of overlapping scales.

As with many sedentary or parasitic gastropods, coralliophilids apparently have no radula, obtaining their nourishment directly from the tissues of their host by means of a muscular proboscis. The eggs of *Coralliophila violacea* are held in capsules under the shell of the female until the pelagic larvae hatch (Demond, 1957), a habit which is unique among neogastropods (Ponder, 1973). The veligers of three of the Hawaiian species were identified from the plankton by J. B. Taylor (1975). All were four-lobed, with a conical protoconch elaborately sculptured with tubercles and sutural cords.

Coralliobia fimbriata (A. Adams, 1854b). Fig. 90 E, F. (Synonym: *Coralliobia cancellata* Pease, 1861a). Length, 20 mm; diameter, 20 mm. *Shell:* flat, dome-shaped, the aperture with a shelf; sculpture of sharp lamellae reticulated by spiral cords; white. *Sculpture:* elevated, thin, sharp lamellae representing previous expansions of the outer lip crossed by four or five strong spiral cords, and fine spiral threads which fimbriate the back of the expanded outer lip. *Aperture:* ovate, with axially striate lamina contracting the aperture. *Color:* white; columella may be pale pink.

Living animals have only occasionally been collected on coral; shells are uncommon in drift and at depths to 300 m.

C. fimbriata is distributed throughout the Indo-West Pacific.

Coralliophila d'orbignyana (Petit, 1851b). Fig. 90 A. (Synonyms: *Rhizochilus exaratus* Pease, 1861a; *Coralliophila deformis* (Lamarck), Edmondson, 1933.) Length, 26 mm; diameter, 21 mm. *Shell:* turbiniform; with spiral threads; gray. *Spire:* teleoconch of four convex whorls, the last whorl the largest; suture canaliculate. *Sculpture:* with occasional, irregular axial folds; spiral sculpture of fine, distinct threads, the interspaces deep and subequal in diameter. *Aperture:* subcircular; lirate within; outer lip thin; with a deep umbilicus and spoon-shaped fasciole. *Color:* gray, aperture white; operculum light yellow.

These coralliophilids are found in the interior of coral blocks or in holes on the undersurface, never on the outside; despite their interior habitat, they are free-moving within the burrow.

C. d'orbignyana has been recorded from several other localities in the Indo-West Pacific.

Coralliophila erosa (Röding, 1798). Fig. 90 B. (Synonyms: *Purpura bulbiformis* Conrad, 1837; *Coralliophila elaborata* H. and A. Adams, 1864; *C. undosa* H. and A. Adams, 1864.) Length, 52 mm; diameter, 35 mm. *Shell:* spindle-shaped to globose, bulbous; with axial ribs and squamose spiral cords; aperture lavender. *Spire:* teleoconch of six or more whorls, the last much the largest and convex; suture impressed.

Sculpture: numerous, close-set, scaly spiral threads crossing variously developed axial ribs. *Aperture:* ovate; outer lip crenulated by the external sculpture and lirate within; operculum dark brown with purpuroid markings. *Color:* gray or white; aperture pale to deep lavender. Animal white; operculum red-brown.

These coralliophilids are free-moving, and it is perhaps because of their free-living habit that they are not so subject to calcareous deposits as are the shells of *C. violacea*. Animals have been collected on outer reefs clinging to living coral, at depths to 160 m off Oahu, and on coral in shallow tide pools on the island of Hawaii. *C. erosa* is recorded in Pleistocene fossil deposits on Oahu and Molokai (Ostergaard, 1928, 1939 as *C. bulbiformis*).

This species occurs throughout the Indo-West Pacific.

Coralliophila sp. cf. *nodosa* (A. Adams, 1854e). Fig. 90 H. Length, 20 mm; diameter, 11 mm. *Shell:* turbinate, ventricose; with bold axial ribs and sharp spiral threads; white suffused with pink, aperture white. *Spire:* protoconch unknown; teleoconch of five convex whorls, the last the largest, inflated; suture impressed. *Sculpture:* bold, rounded axial ribs, about eight on the last whorl, seven on the penultimate whorl; interspaces shallow, of lesser diameter than the ribs; ribs and interspaces crossed by sharp spiral threads of varying size. *Aperture:* ovate; outer lip thin; distinctly lirate within; columella smooth; siphonal canal ending with a spur. *Color:* white to brown on the apical whorls, flushed with pink; aperture white.

These coralliophilids are rare, found at depths of 100 m.

C. nodosa was described from the Philippines but Hedley (1913) suggests the species is characteristic of New South Wales. The Hawaiian shells are almost indistinguishable from Adams' type (in the British Museum (Natural History)) except that the holotype is gray-white rather than flushed with pink. These shells are distinguished from those of *Fusus abnormis* Smith, 1878, from the Andaman Islands by the shorter spire and rosy color. They are smaller and more graceful than the shells of *C. erosa* and more solid and shorter than those of *C. d'orbignyana*.

Coralliophila violacea (Kiener, 1836). Fig. 90 C. (Synonym: *Coralliophila neretoidea* [*sic*] Lamarck, Edmondson, 1933.) Length, 36 mm; diameter, 30 mm. *Shell:* dome-shaped, angulated; with a thick, calcareous deposit; aperture dark purple. *Spire:* teleoconch of three or four whorls, the last angulated at the periphery; suture impressed. *Sculpture:* fine, spiral threads. *Aperture:* triangular; lirate within, outer lip thin and smooth; operculum dark red-brown. *Color:* white, surface usually encrusted with a thick calcareous deposit; aperture dark violet.

These animals are commonly found attached to coral, usually *Porites*, at the outer edge of reefs and to depths of 160 m. The animals are sessile and when removed from the coral leave a distinct scar. *C. violacea* is recorded from Pleistocene fossil deposits on Oahu and Molokai by Ostergaard (1928; 1939).

The shells are very variable in shape and are widely distributed in the Pacific, ranging as far east as Clipperton and the Galapagos Islands (Keen, 1971, as *C. neritoides* (Lamarck, 1816)).

Latiaxis cuspidifera (Dall, 1924). Fig. 90 I. Length, 23 mm; diameter, 17 mm. *Shell:* biconic-turbiniform; axially ribbed and spirally sculptured by peripheral spines;

white. *Spire:* five or six turreted, angular whorls; suture deep and channeled. *Sculpture:* eight low axial ribs on a last whorl 17 mm in diameter, interspaces subequal; spirally sculptured by sharp threads which imbricate the ribs and peripherally form projecting flanges. *Aperture:* wide; outer lip flaring basally, crenulate by the external sculpture and lirate within; siphonal canal imbricate. *Color:* white.

This species occurs at depths of from 30 to 600 m.

L. cuspidifera was described from the Hawaiian Islands.

Latiaxis japonicus (Dunker, 1882). Fig. 90 L. Length, 41 mm; diameter, 26 mm. *Shell:* spindle-shaped, solid; with low axial ribs, a single row of peripheral spines and coarse, scaly spiral cords; white. *Spire:* protoconch of one and one-half smooth, glassy whorls; teleoconch of eight turreted whorls; suture obscure. *Sculpture:* twelve low, rounded, broad axial ribs; spiral sculpture of a partly spinose imbricated cord in front of the suture and smaller cords on the shoulder, a peripheral cord of concave, triangular, slightly reflexed and recurved closely imbricated spines, and imbricated cords with interspaces of about equal diameter. *Aperture:* subovate with internal lirae, the edge sculptured by the external sculpture; siphonal canal long. *Color:* white or gray; aperture white.

Shells were dredged by the *Albatross* at depths of 156 to 356 m.

L. japonicus has been recorded from central Honshu and further south in Japan at depths of 100 to 160 m (Kira, 1962).

Latiaxis tosanus Hirase, 1908. Fig. 90 J. Length, 29 mm; diameter, 20 mm. *Shell:* biconic-turbiniform; with elongate, flattened spines at the periphery of the whorls and scaly spirals; white, aperture pink. *Spire:* protoconch of about one and one-half whorls; teleoconch of seven whorls separated by an obscure, appressed suture. *Sculpture:* axial ribs barely noticeable; whorls shouldered with a series of long, slightly recurved, anteriorly guttered spines; spiral sculpture of six or seven imbricated cords between the suture and the last whorl and seven on the last whorl below the spines, all imbricate and subspinose, the interspaces narrower. *Aperture:* subovate, equal in length to the spire; lirate within; outer lip thin and crenate by the external sculpture; siphonal fasciole conspicuously spinose over a perforate umbilicus. *Color:* light brown, aperture flush pink.

Shells of *L. tosanus* were dredged by the *Albatross* at depths of 120 m.

This species is recorded from the Pacific coasts of Shikoku at depths of 60 to 100 m (Kira, 1962).

Magilopsis lamarckii (Deshayes, 1863). Fig. 90 D. Length, 17 mm; diameter, 8 mm. *Shell:* spindle-shaped with the aperture drawn out as a long canal; white or gray. *Spire:* projecting, tapering; suture obscure. *Sculpture:* imbricated spiral threads; beachworn shells may have rounded spiral cords reticulated by sharp axial lamellae. *Aperture:* ovate, oblique; columella arched. *Color:* white or gray.

Specimens are uncommon. The animals live deep in coral, usually *Fungia*. They are apparently unattached in their burrows, but the burrows are so narrow that the mollusks cannot turn within them. Shells have been dredged at depths of 50 to 100 m off Waikiki, Oahu.

M. lamarckii was described from Réunion and is reported from several localities within the Indo-West Pacific (Demond, 1957); and Gohar and Soliman (1964) discuss the habits of this species at Al-Ghardaqa, Egypt.

Quoyula madreporarum (Sowerby, 1834). Fig. 90 G. Length, 30 mm; diameter, 20 mm. *Shell:* oval, dome-shaped; white. *Sculpture:* faint spiral striae. *Aperture:* wide; columella forming a shelf; operculum muricoid, about one-sixth as long as the aperture, claret color with pale edges. *Color:* white, aperture pink or purple; the surface of the shell usually obscured by limy deposits.

Specimens are common in both shallow and deep water. The animals live embedded on coral and their shells are contoured as is the substrate; they deposit a shelly plate at the site of the habit.

Q. madreporarum apparently occurs throughout the Indo-West Pacific, and is also known from the west coast of the Americas (Keen, 1958).

Additional Records

Rhizochilus antipathicus (Steenstrup, 1850) (Fig. 90 K) with a pyriform, thin, white shell, a low, attenuate, obsoletely ribbed spire, and angular, inflated last whorl has been recorded at depths of 41 m inside soft coral attached to the black coral *Antipathes grandis* (Gage, 1962). This species was described from the Indian Ocean.

Edmondson (1933; 1946) reports *Magilus striatus* Ruppell and Demond (1957) *Magilus antiquus* Montfort, 1810, from Hawaii, but I have seen no authentic records of these mollusks.

Superfamily BUCCINACEA

Buccinacean shells are fusiform, from 2 to 3 mm to more than 30 mm in length. They lack the varices of muricacean shells.

These neogastropods are active predators and carrion feeders. Anatomically they are distinguished from muricaceans in that they lack an accessory boring organ and accessory salivary glands, and the esophagus is somewhat simplified (Ponder, 1973). The hypobranchial gland produces copious quantities of mucus and other colorless secretions but no purple fluid as in the muricaceans. The foot usually bears an operculum, although it is absent in some columbellids.

Buccinaceans for which there are data on life histories have, for the most part, direct development; in Hawaiian waters, however, J. B. Taylor (1975) has shown that at least 13 species, representing 39 percent of the species recorded, have a planktonic veliger larval stage, and protoconchs of most of the other species are those associated with a pelagic larval stage.

Family **Buccinidae**

The shells of buccinids are variable in size, with large shells (more than 50 mm in length) found mostly in temperate waters. The shell is usually thick and spindle-

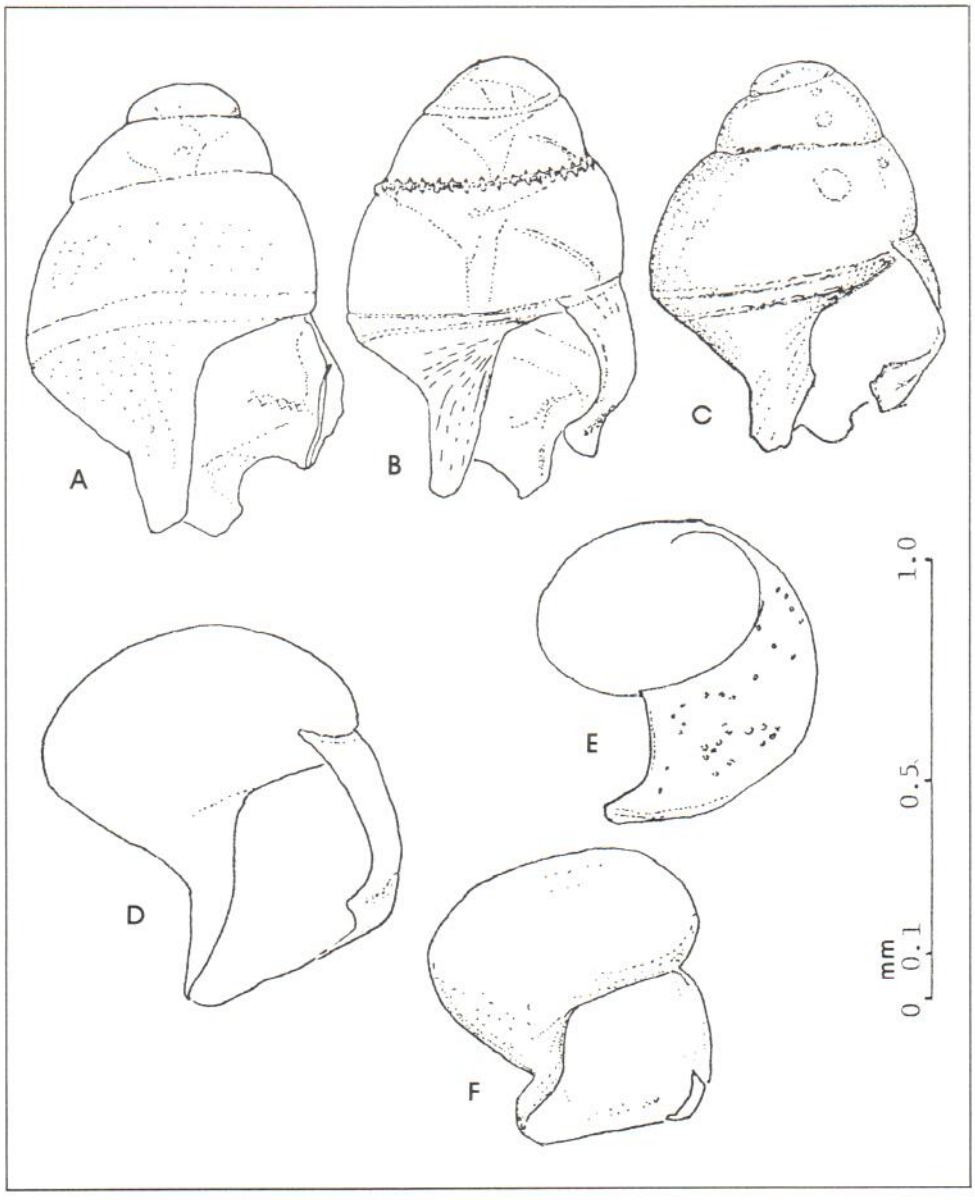


Figure 91.—Buccinid and fasciolarid premetamorphic protoconchs. A. *Latirus nodatus*. B. *Engina albocincta*. C. *Prodotia iostomus*. D. *P. ignea*. E, F. *Cantharus farinosus*. (All from J. B. Taylor, 1975.)

shaped and has a wide aperture and long siphonal canal. As Ponder (1972b) indicated, however, the generic limits of buccinids are difficult to define because the shells, radulae, and operculae have few characters that allow for clear-cut taxonomic differentiation. Malacologists do not agree on either genera or subgenera (see, for example, Ponder, 1972b; Cernohorsky, 1971a, 1975a).

Of the 11 species recorded in Hawaiian waters, eight are distributed throughout the Indo-West Pacific, two are apparently restricted to the Pacific Basin, and two are possibly endemic to the Hawaiian Islands.

The commonly found buccinids may be keyed as follows:

1. Fusiform; smooth or moderately sculptured with axial ribs and spiral threads 2
   Ovate or biconic; with prominent axial ribs and nodules 6

2. (1) Shell of moderate size (20 mm), siphonal canal long, lips weakly dentate; shades of brown or lavender 3
   Shell small (6-15 mm); white or cream spotted with brown 5

3. (2) With beaded spiral threads; brown, lavender or cream with brown 4
   Predominantly smooth; cream maculated with brown ..... *Prodotia ignea*

4. (3) Lavender splashed with chestnut ..... *P. iostomus*
   Light brown or cream flushed with darker brown ..... *Phos varicosus*

5. (2) Adult shell lacking apical whorls ..... *Caducifer decapitata*
   Adult shell with apical whorls ..... *C. nebulosa*

6. (1) Brown or patterned with brown 7
   Pink spirally banded with black and yellow ..... *Clivipollia fragaria*

7. (6) Shell of moderate size (12-20 mm) 8
   Shell small (6 mm); red-brown banded with white ..... *Engina albocincta*

8. Shell unicolored 9
   White with black and orange nodules ..... *Engina alveolata*

9. (8) Parietal callus wrinkled; aperture white ..... *Cantharus farinosus*
   Parietal callus not wrinkled; aperture pink ..... *Clivipollia costata*

Caducifer decapitata (Reeve, 1844). Fig. 92 A, B. (Synonym: *Clathurella fuscomaculata* Pease, 1860.) Length, 14 mm; diameter, 5 mm. *Shell:* fusiform, slender; truncated; dark brown maculated with white. *Spire:* protoconch tall, of three and one-half smooth white whorls; teleoconch of three to four whorls separated by a barely impressed suture. *Sculpture:* spiral sculpture only, of narrow threads separated by three or four secondary threads. *Aperture:* ovate, narrow; outer lip barely thickened; lirate within; canal slightly recurved. *Color:* cream with splashes of brown in juveniles; dark brown with white maculations in adults. *Animals:* head and tentacles red-brown; foot white.

Specimens of *C. decapitata* are found in tide pools where there is considerable surf action and shells have been dredged from depths to 100 m. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

This species occurs throughout the Indo-West Pacific, from Mauritius in the Indian Ocean to Fiji. The shells are distinguished from those of *C. truncata* (Hinds, 1844) by their weaker sculpture (Ponder, 1972c).

Caducifer nebulosa (Gould, 1860). Fig. 92 K. (Synonym: *Triton pusilla* Pease, 1861b, non *Columbella [Zafrona] pusilla* Sowerby, 1844.) Length, 8 mm; diameter, 3 mm. *Shell:* tritonlike; axial ribs crossed by beaded spiral cords; white variegated with brown. *Spire:* protoconch of three or four smooth, conical, white whorls; teleoconch of five inflated whorls; suture impressed. *Sculpture:* axial ribs crossed by spiral cords forming nodules at the junctions; interspaces finely axially striated; base grooved. *Aperture:* ovate; outer lip thick and lirate within, with a shallow sutural sinus; columella straight; canal recurved. *Color:* white or horn with irregular, axially oriented brown spots or lines.

Specimens are occasionally found under rocks in tide pools, but these buccinids are more common at depths of 10 m and beachworn specimens are fairly common in drift.

C. nebulosa was described from the China Seas; *Triton pusilla* was described from the Hawaiian Islands. Iredale's (1916) suggestion that *Triton pusilla* Pease, is a synonym of *Zafrona isomella* (Duclos, 1840) is not borne out by a comparison of the figure of *Z. isomella* with the Hawaiian shells. Although Gould (1860) described the species as a columbellid, the protoconch and aperture are buccinid and the species is here tentatively associated with *Caducifer*, characterized by the tall spire.

Cantharus farinosus (Gould, 1850). Figs. 91 E, F; 92 D. (Synonym: *Hindsia angicostata* Pease, 1860.) Length, 12 mm; diameter, 6 mm. *Shell:* ovate, solid; with undulating axial ribs crossed by sharp spiral cords; parietal callus wrinkled; light brown with darker. *Spire:* Protoconch of one and one-half bulbous, white whorls; teleoconch of six to seven convex, inflated whorls plus the protoconch; suture shallow, channeled. *Sculpture:* convex, broad, undulating axial ribs, the interspaces about equal in diameter; spiral sculpture of sharp cords and finer interstitial threads overriding the axials; primary spiral cords forming nodulous edges on the ribs. *Aperture:* ovate; outer lip thickened externally; with four or five lirae internally; columella arched and covered by a wrinkled callus reflected over the last whorl; canal slightly produced and recurved. *Color:* light brown, axial ribs darker; last whorl with a spiral band of white.

These shells are rather uncommon, found most often at depths of 80 to 160 m. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

C. farinosus was described from Kauai. Cernohorsky's (1977a) description of a "muricid" protoconch in a supposed specimen of *C. farinosus* from Fiji is in contrast to the clearly buccinid protoconch found in the Hawaiian shells (Fig. 91 E, F), and the Fijian shells may not represent this species.

Cantharus pulcher (Reeve, 1846). Fig. 96 F. Length, 20 mm; diameter, 8 mm (juvenile shell). *Shell:* adult — biconic; juvenile — fusiform; with spiral cords and thick axial ribs; brown spirally banded with cream. *Spire:* protoconch of two and

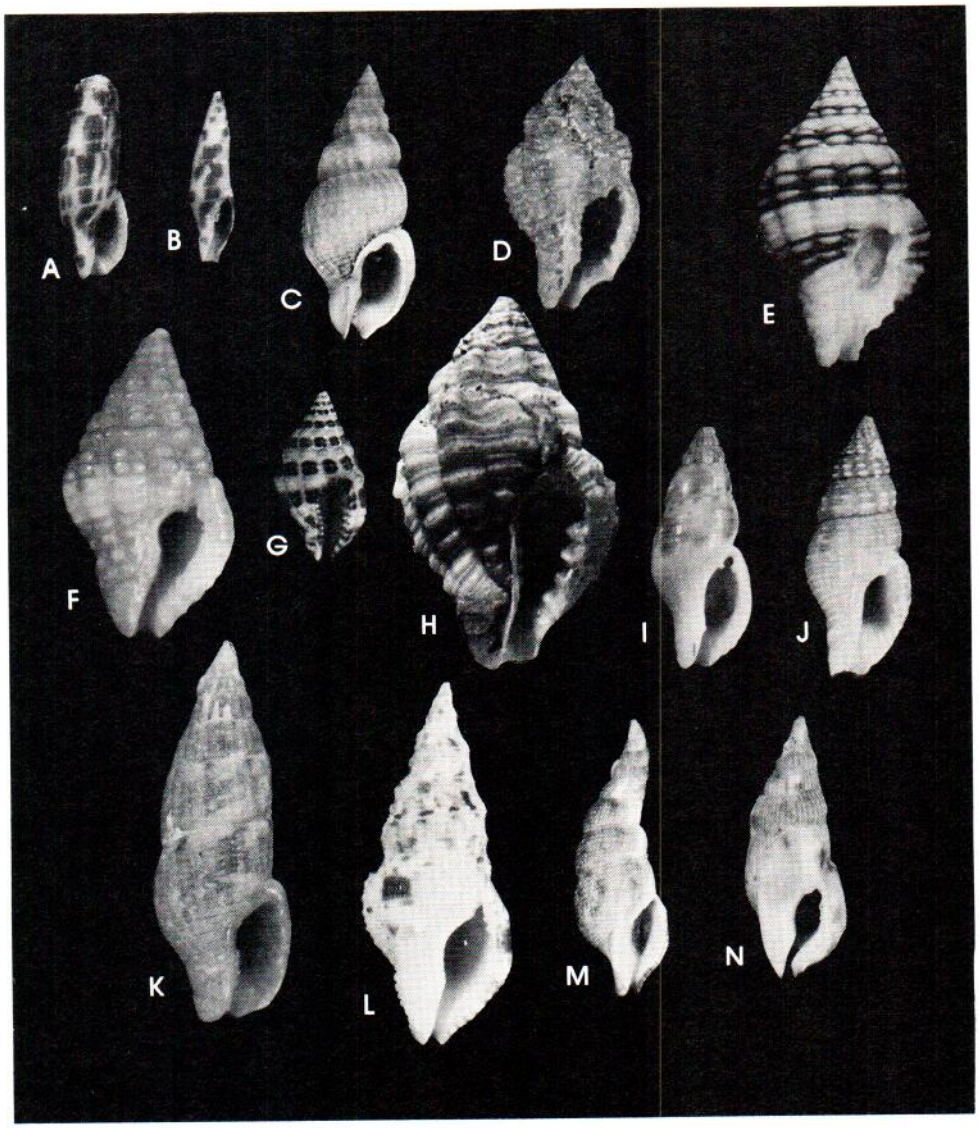


Figure 92.—**Buccinidae.** A, B. *Caducifer decapitata,* length 14 mm. C. *Phos varicosus,* length 21 mm. D. *Cantharus farinosus,* length 12 mm. E. *Clivipollia fragaria,* length 20 mm. F. *Engina albocincta,* length 6 mm. G. *E. alveolata,* length 20 mm. H. *Clivipollia costata,* length 19 mm. I. *Prodotia ignea,* length 21 mm. J. *P. iostomus,* length 20 mm. K. *Caducifer nebulosa,* length 8 mm. L. *Colubraria muricata,* length 67 mm. M. *C. tortuosa,* length 47 mm. N. *C. obscura,* length 30 mm.

one-half inflated, conical, white whorls; teleoconch of six slightly convex whorls; suture shallow, barely impressed. *Sculpture:* broad axial ribs, about eight on the last whorl, separated by narrower but shallow interspaces; ribs and interspaces crossed by thick spiral cords and the interspaces with intercalary threads. *Aperture:* elongate-ovate in juveniles, narrow in adults; about one-half the height of the spire; in adults outer lip thick and varicose behind, with five or six denticles, columella with folds; in juveniles

outer lip thin but backed by an axial rib, lirate within, columella with small folds. *Color:* background red-brown, spiral cords, siphonal canal and apex cream.

These buccinids are rare in Hawaiian waters and only juvenile shells have been found, at depths of 46 to 200 m.

C. pulcher was described from the Philippine Islands. Cernohorsky (1972a) reports it westward from the Fiji Islands. It is also found in New Guinea (Ponder, 1972c) and the Line and Ryukyu islands.

Clivipollia costata (Pease, 1860). Fig. 92 H. (Synonym: *Peristernia thaanumi* Pilsbry and Bryan, 1918.) Length, 19 mm; diameter, 10 mm. *Shell:* ovate-biconical, solid; axial ribs crossed by sharp spiral keels; yellow-brown, aperture pink. *Spire:* protoconch of three and one-half glistening, pink whorls; teleoconch of four to six slightly inflated whorls; suture channeled. *Sculpture:* strong axial ribs crossed by numerous fine, sharp spiral keels which become somewhat nodulous at the ribs; interspaces spirally and axially threaded with secondary threads. *Aperture:* oblong-ovate; outer lip thick externally, with a sharp edge and five to six intramarginal denticles; columella straight, covered by a thin callus which projects outward and with three to four plaits. *Color:* yellow-brown (orange-yellow in subfossils); aperture white or tinted with pink. Periostracum thin, brown.

Specimens of *C. costata* have been recorded from depths of 40 m; beachworn specimens are occasionally found in drift along the shores of northern beaches.

This species was described from the Hawaiian Islands and has been recorded from Clipperton Island (as *Peristernia thaanumi*, Hertlein and Allison, 1966).

Clivipollia fragaria (Wood, 1828). Fig. 92 E. Length, 20 mm; diameter, 11 mm. *Shell:* biconic, thick and solid; with axial ribs and sharp spiral cords; pink spirally banded with black and with a thin golden yellow band on the ribs. *Spire:* protoconch of one and one-half smooth pink whorls; teleoconch of five whorls, the last the largest; suture deep. *Aperture:* narrow, with six teeth inside the lip; sulcus shallow; columella with two plaits; siphonal canal recurved. *Color:* pink spirally banded with black and with thin cords of golden yellow on the ribs.

This gastropod is rarely found, recorded from depths of 15 to 30 m off Oahu and Kauai.

C. fragaria is a well-known species throughout the Indo-West Pacific.

Engina albocincta Pease, 1860. Figs. 91 B; 92 F. Length, 6 mm; diameter, 3 mm. *Shell:* biconic-ovate; with axial ribs crossed by fine spiral cords; red-brown with a single white spiral band on the last whorl. *Spire:* Protoconch of three and one-half conical, purple whorls, suture of abapical whorl crimped; teleoconch of five or six whorls, the last whorl slightly shouldered; suture shallow. *Sculpture:* broad, convex axial ribs separated by subequal, deep interspaces; spiral sculpture of fine cords overriding the ribs and interspaces, the interstices subequal and smooth. *Aperture:* oval; outer lip thickened, with five internal denticles and a shallow sinus; columella straight. *Color:* red-brown (yellow in subfossil specimens) with a single white spiral band across the periphery of the last whorl.

Occasional specimens are found on the undersurfaces of rocks in tide pools

subject to considerable wave action. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

This species was described from the Hawaiian Islands.

Engina alveolata (Kiener, 1836). Fig. 92 G. Length, 20 mm; diameter, 8 mm. *Shell:* biconic; with nodulose axial ribs and spiral threads; white, nodules black and orange. *Spire:* teleoconch of five slightly convex whorls; suture shallow. *Sculpture:* nodulose axial ribs crossed by fine spiral threads with finer threads in the interspaces. *Aperture:* oval; outer lip thickened, with six or seven denticles and a shallow sinus. *Color:* white, with a double row of black nodules and smaller orange nodules; edge of lip dark brown, denticles white.

These buccinids are rare, recorded from depths of 10 m off Oahu.

E. alveolata occurs throughout the Indo-West Pacific from East Africa to Polynesia and southern Japan.

Phos varicosus (Gould, 1849). Fig. 92 C. Length, 21 mm; diameter, 8.5 mm. *Shell:* elongate-conic; with nodular axial ribs and spiral threads; cream, sometimes splashed with dark brown. *Spire:* high; teleoconch of about six slightly convex whorls which are slightly shouldered at the suture; suture impressed. *Sculpture:* fine axial ribs crossed by finer spiral threads, the ribs and cords slightly nodular at their intersections. *Aperture:* oval; outer lip slightly thickened; interior prominently lirate; columella callused on the lower part and with two or three folds anteriorly; parietal wall with a denticle; siphonal canal twisted. *Color:* fawn to cream, spirally banded or splashed with darker brown.

These buccinids are rarely found, dredged at depths of 100 to 600 m.

P. varicosus was described from the Philippine Islands.

Prodotia ignea (Gmelin, 1791). Figs. 91 D; 92 I. (Synonym: *Pisania tritinoides* [*sic*] Reeve, Edmondson, 1933.) Length, 21 mm; diameter, 8 mm. *Shell:* fusiform, slender; predominantly smooth; cream maculated with brown. *Spire:* protoconch of one and one-half bulbous glistening tan or honey-colored whorls; teleoconch of six to eight slightly convex whorls; suture impressed; spire equal in length to the aperture. *Sculpture:* apical whorls with prominent, straight, beaded axial ribs; later whorls with microscopic growth striae becoming grooved at the base. *Aperture:* ovate, rather broad; outer lip thin, flaring basally; smooth; columella straight and smooth; with a nodule in the throat. *Color:* cream, variously maculated or splashed with brown.

These buccinids occur in shallow water, in tide pools and shoreward of fringing reefs. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

P. ignea is a well-known species in the Indo-West Pacific.

Prodotia iostomus (Gray in Griffiths and Pidgeon, 1834a). Figs. 91 C; 92 J. (Synonym: *Pisania billeheusti* Petit, Edmondson, 1946.) Length, 20 mm; diameter, 8 mm. *Shell:* fusiform, slender; lightly axially ribbed and with fine slightly granular spiral threads; lavender splashed with chestnut. *Spire:* protoconch of two and one-half conical, glistening pink whorls; teleoconch of six to eight slightly convex whorls; suture impressed. *Sculpture:* low axial ribs more prominent on the apical whorls than

on the abapical whorls, the interspaces shallow and of lesser diameter than the ribs; spiral sculpture of widely spaced cords forming beads at the junctions of the ribs, the spiral cords separated by three or four interstitial threads. *Aperture:* ovate; equal in length to the spire; lirate within; outer lip thick and dentate; columella callused and irregularly plicate. *Color:* lavender blotched and splashed with chestnut. *Animal:* exposed parts cream spotted with maroon; sole of foot cream.

This species is common in shallow water and to depths of 160 m. There is a four-lobed planktonic veliger larva (J. B. Taylor, 1975).

This species has a complex taxonomic history resulting in part from the variation seen in the shells. A slender form was named *Phos billeheusti* Petit, 1853, and wider variants with somewhat different color patterns *Buccinum gracile* Reeve, 1846, and *B. marmoratum* Reeve, 1846. Cernohorsky (1975a) resurrected *Triton iostoma* because the Reeve names are primary homonyms. The species is widespread within the Indo-West Pacific.

Family **Columbellidae**

Columbellid shells are distinguished by their more or less fusiform shapes and polished, often brightly colored shells. The outer lip is denticulate and there may be folds on the columella. Despite these more or less consistent features, columbellids are remarkable for displaying an enormous range of individual variation which has resulted in some complex species identification problems. The taxonomic issues are further complicated by the numerous genera and subgenera which have been proposed for the family. The genera found in Hawaiian waters may be keyed as follows:

1. Shell fusiform to fusiform-ovate 2
   Shell broad-shouldered, outer lip prominent ..... *Euplica*

2. (1) With axial ribs confined to the apical whorls, extending the length of the shell, or with beaded sculpture 3
   Shell predominantly smooth ..... *Mitrella*

3. With axial ribs extending the length of the shell ..... *Seminella*
   With axial ribs confined to apical whorls only ..... *Anachis*

Anatomically, columbellids exhibit both specialized and primitive features. Some are herbivorous (Marcus and Marcus, 1962), others carnivorous (Abbott, 1974). The egg capsules are hemispherical structures deposited on hard substrates (Thorson, 1940). All the Hawaiian columbellids have protoconchs associated with a pelagic veliger stage, but there are two types of planktonic protoconchs: a microscopically axially ribbed form in *Euplica* and *Mitrella rorida;* and a smooth form in the remaining species of *Mitrella,* and in *Anachis* and *Seminella* (J. B. Taylor, 1975). Veligers with the ribbed protoconchs have four or five velar lobes, those with the smooth protoconchs have two to four velar lobes (J. B. Taylor, 1975).

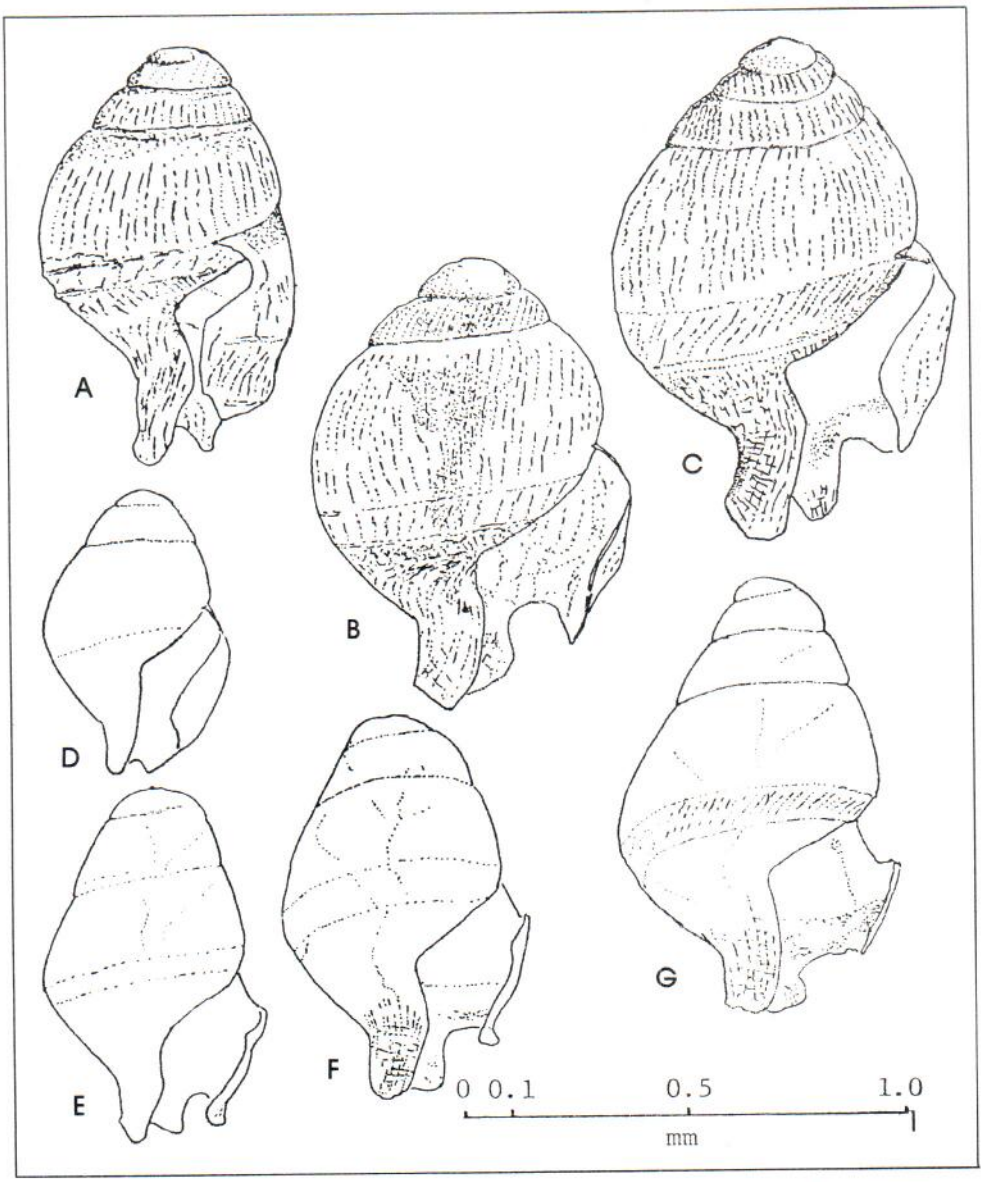


Figure 93.—**Columbellidae.** Premetamorphic protoconchs. A. *Euplica turturina*. B. *E. varians*. C. *Mitrella rorida*. D. *Seminella virginea*. E. *Mitrella bella*. F. *M. margarita*. G. *Anachis miser*. (From J. B. Taylor, 1975.)

Anachis miser (Sowerby, 1844). Figs. 93 G; 94 F, G. (Synonyms: *Columbella zebra* Gray, Bryan, 1915; *C. lineolata* Kiener, Edmondson, 1933.) Length, 15 mm; diameter, 6 mm. *Shell:* fusiform, solid; smooth or axially ribbed; white axially striped with black. *Spire:* protoconch of two inflated, convex, smooth, white whorls; teleoconch of seven or eight convex whorls; suture impressed. *Sculpture:* variable — smooth except for microscopic growth striae or with distinct axial ribs; base spirally

grooved. *Aperture:* narrow; outer lip thin and smooth; columella and canal straight. *Color:* variable — white axially lineated with jagged black marks; sometimes white with black ribs.

A. miser is common in shallow water; the animals are usually found on the fronds of the algae *Sargassum* and *Galaxiura*, and, occasionally, on *Ulva* on the surf-washed edges of benches. The veliger larva is bilobed (J. B. Taylor, 1975).

This species is widely distributed throughout the Indo-West Pacific.

Euplica turturina (Lamarck, 1822). Figs. 93 A; 94 A. (Synonyms: *Columbella palumbina* Gould, 1845; *C. sandwichensis* Pease, 1861c.) Length, 10 mm; diameter, 5 mm. *Shell:* columbelliform; smooth; cream splashed and lineated with varying shades of brown. *Spire:* protoconch of one and one-half pale pink, glassy, conical whorls which are microscopically axially ribbed; teleoconch of five whorls, the last the largest and inflated at the periphery; suture linear. *Sculpture:* axially noduled on the two apical whorls, remaining whorls smooth and with microscopic growth striae. *Aperture:* narrow, outer lip reflected inward and dentate within; columella with two or more folds. *Color:* cream splashed and lineated with fawn and chestnut brown and with a row of white spots at the suture.

These shells are very common in beach drift at Midway and others of the leeward islands, but are known only from occasional specimens dredged at depths of more than 50 m off Oahu in the windward islands in the Hawaiian chain. There is a five-lobed planktonic veliger larva (J. B. Taylor, 1975).

E. turturina occurs throughout the Indo-West Pacific, from Ceylon and the Cocos-Keeling atoll eastward (Demond, 1957) where it is a common inhabitant of reef flats. Comparison of the Hawaiian shells with those of the widely distributed species indicates no consistent differences in protoconch, sculpture, or color patterns which would warrant recognition of a distinct species *(Euplica palumbina)* as suggested by Rehder and Randall (1975).

Euplica varians (Sowerby, 1832). Figs. 93 B; 94 B-D. (Synonym: *Columbella pacifica* Gaskoin, 1852.) Length, 10 mm; diameter, 6 mm. *Shell:* solid, with a wide shoulder; noduled below suture on last whorl; cream, splashed, dashed, or lineated with black. *Spire:* protoconch of three and one-half polished, microscopically axially ribbed, white, bulbous and eccentrically placed whorls; teleoconch of four or five whorls, the last the largest; spire projecting, attenuate; suture shallow. *Sculpture:* apical whorls and shoulder of last whorl noduled; remainder of last whorl smooth; canal spirally grooved. *Aperture:* ovate; outer lip thickened and denticulate within; columella plicate. *Color:* variable — white, the base stained dark blue or variously splashed or lineated with black or brown. Periostracum thin and transparent but hairy apically, forming axial ribs when dry.

These columbellids are abundant, found on rocks in tide pools, in shallow waters shoreward of fringing reefs and in beds of the sea anemones *Zoanthus* and *Palythoa*. There is a five-lobed planktonic veliger (J. B. Taylor, 1975).

E. varians was described from the Galapagos, but the name is widely used for the species in collections from the Indo-West Pacific. *Columbella pacifica* Gaskoin was described from the Hawaiian Islands from shells collected by Thomas Nuttall.

Mitrella bella (Reeve, 1859). Figs. 93 E; 94 E. Length, 10 mm; diameter, 4 mm. *Shell:* fusiform, slender; last whorl angular; smooth; cream splashed with light brown. *Spire:* protoconch of three thin, smooth, inflated white whorls; teleoconch of six slightly convex whorls; suture impressed. *Sculpture:* smooth; base with eight or nine spiral threads and grooves. *Aperture:* ovate; outer lip thick, denticulate and lirate within; columella with four plaits. *Color:* variable — ivory splashed with light brown or reticulated with light brown. Periostracum thin, light colored.

This species occurs at depths of from 20 to 80 m. The planktonic veliger is four-lobed (J. B. Taylor, 1975).

M. bella was described from the Philippine Islands. The shells are distinguished from those of *M. fusiformis* by the angular last whorl, larger size, and color pattern of splashes of brown.

Mitrella fusiformis (Pease, 1868e). Fig 94 H, I. (Synonyms: *Columbella lineata* Pease, 1861a; *C. sagitta* Gaskoin, Tryon, 1883.) Length, 6 mm; diameter, 2.5 mm. *Shell:* fusiform; shining; smooth; cream colored, reticulated or lineated with dark brown. *Spire:* protoconch paucispiral, of one and one-half inflated, flat-topped, smooth, white whorls; teleoconch three to four times the length of the aperture plus the canal; seven barely convex whorls; suture slightly impressed. *Sculpture:* smooth, spirally striated at the base only. *Aperture:* narrow; outer lip often thick and denticulate; sinuate at the suture; siphonal canal wide and slightly recurved. *Color:* variable — ivory with reticulations, lineations or spiral bands of dark brown.

This is one of the most abundantly occurring of gastropods in the Hawaiian Islands, the animals found in algae on the upper surfaces and sides of rocks in tide pools and in the shallow waters shoreward of fringing reefs.

M. fusiformis is widely distributed throughout the Indo-West Pacific.

This species has a confused taxonomic history. It is frequently seen in collections as *Columbella sagitta* Gaskoin, 1852, a name assigned by Tryon (1883) who questioned the West Indian locale of Gaskoin's species. The holotype of *C. sagitta* (in the British Museum (Natural History)) differs from shells of *M. fusiformis* in its larger size, its angular rather than convex last whorl, its obliquely set protoconch, and its color pattern of tent-shaped markings.

Mitrella margarita (Reeve, 1859). Figs. 93 F; 94 K, L. (Synonyms: *Columbella venusta* 'Pease,' Pace, 1902, *nomen nudum; C. moleculina* Duclos, Tinker, 1952.) Length, 9 mm; diameter, 5 mm. *Shell:* ovate, smooth, shining; ivory interrupted by yellow-brown lineations and freckles. *Spire:* protoconch of two and one-half narrow whorls which sit peglike at the apex of the teleoconch; teleoconch of seven inflated whorls; suture flush. *Sculpture:* apical whorls occasionally obsoletely noduled, remaining whorls smooth. *Aperture:* narrow; outer lip thick and dentate within; columella with three or four plicae. *Color:* ivory stained with yellow-brown lineations and freckles, usually with a spiral of white and brown below the suture.

Although shells are commonly found in beach drift, living animals are only occasionally encountered in tide pools and in shallow waters inshore of fringing reefs, and at depths to 100 m. The planktonic veliger is bilobed, and newly metamorphosed juveniles are molluscivorous (J. B. Taylor, 1975).

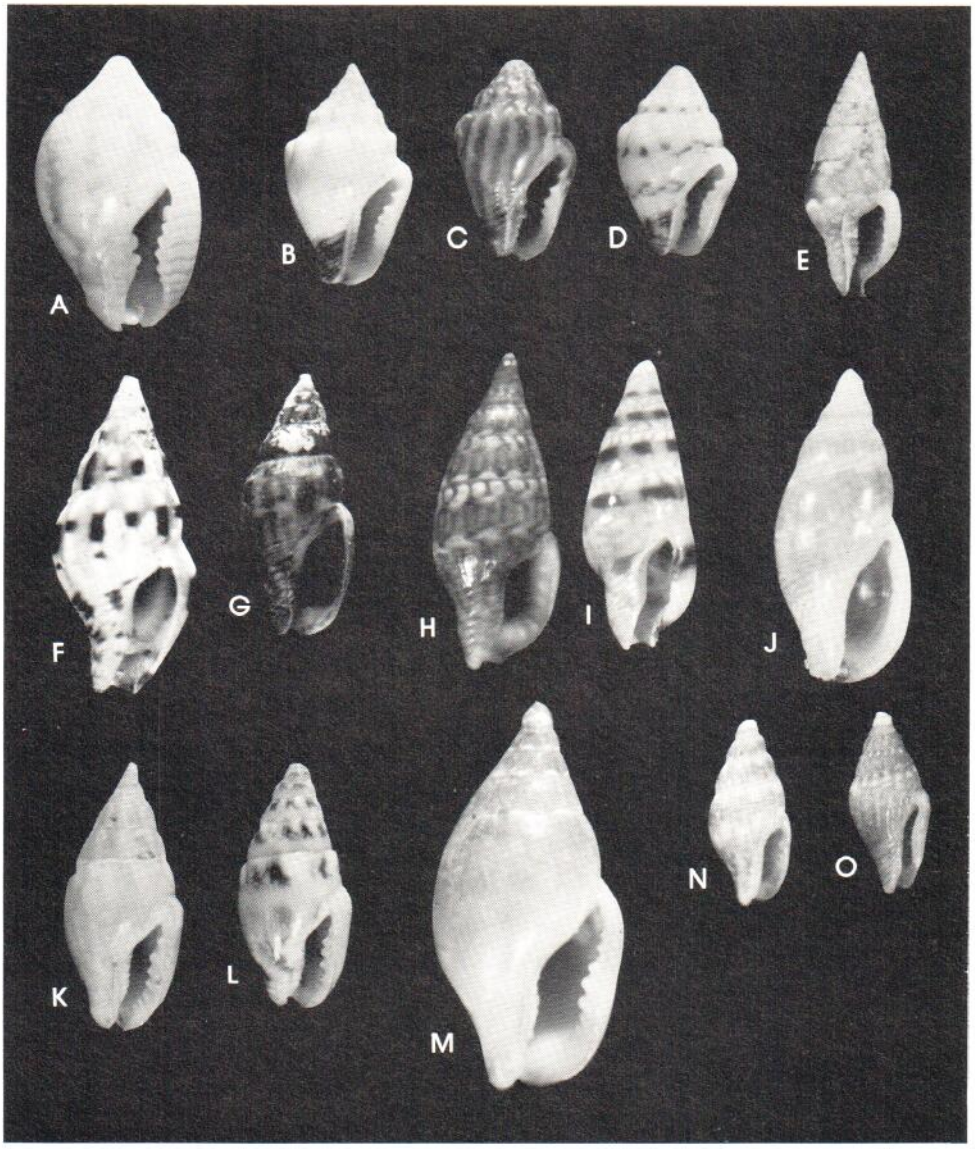


Figure 94.—**Columbellidae.** A. *Euplica turturina*, length 10 mm. B, C, D. *E. varians*, color forms, (B) length 10 mm; (C) length 9 mm, (D) length 10 mm. E. *Mitrella bella*, length 10 mm. F, G. *Anachis miser*, color forms, (F) length 10 mm, (G) length 8 mm. H, I. *Mitrella fusiformis*, color forms, length 6 mm. J. *M. rorida*, length 5 mm. K, L. *M. margarita*, (K) length 11 mm, (L) length 9 mm. M. *Euplica livescens*, length 11 mm. N. *Seminella virginea*, length 3 mm. O. *S. smithi*, length 3.5 mm.

M. margarita was described from the Hawaiian Islands, but is distributed throughout the Indo-West Pacific and occurs in Mauritius and New Caledonia (Hervier, 1899). *Columbella digitale* Lesson, 1842a, may be an earlier name for this species but it was not figured, and the description is too general for specific identification.

Mitrella rorida (Reeve, 1859). Figs. 93C; 94 J. (Synonyms: *Columbella pellucida* Pease, 1861a; *C. moleculina* Duclos, Mant, 1923.) Length, 5 mm; diameter, 2.5 mm. *Shell:* fusiform, thin; white or horn-colored with a network of chestnut markings and a spiral of white dashes. *Spire:* protoconch of three and one-half white, microscopically axially ribbed whorls, the two abapical whorls the largest and with microscopic axial striae, the apical whorls slightly eccentric; teleoconch twice the length of the aperture plus canal, of six to seven smooth, convex whorls separated by a faintly impressed suture. *Sculpture:* microscopically axially striate on the apical whorls and on the base; remaining whorls smooth. *Aperture:* oblong-ovate; outer lip flaring slightly basally, thin and simple or very minutely denticulate; columella arched, smooth. *Color:* variable — white or horn-colored, patterned with a network of chestnut or with a spiral of oblong brown spots, usually with a spiral of opaque white spots peripherally on the last whorl. *Animal:* foot white with a triangular brown spot on the anterior dorsal surface; proboscis speckled with green; tentacles white, splashed with brown near the eyes; siphon transparent white flecked with opaque white.

These gastropods are occasionally found under rocks in beds of the sea anemones *Zoanthus* and *Palythoa*. They are more active than *M. fusiformis*. There is a five-lobed planktonic veliger larva, and newly metamorphosed juveniles are molluscivorous (J. B. Taylor, 1975). Shells are recorded in Pleistocene fossil deposits on Oahu (Ostergaard, 1928, as *Columbella moleculina*).

This species is widely distributed throughout the Indo-West Pacific, and appears under a variety of names in collections. While *Columbella moleculina* Duclos 1840 may be an earlier name for the species, there is some question as to its identity, several workers assigning the name to a heavier, more ovate shell than the Hawaiian forms. Because the Hawaiian specimens are always light and thin-shelled, and quite comparable with the types of *M. rorida* Reeve in the British Museum (Natural History), that name is used here.

Seminella smithi (Angas, 1877). Fig. 94 O. Length, 3.5 mm; diameter, 1 mm. *Shell:* fusiform; with keeled axial ribs; brown with a cream-colored spiral thread about the periphery of the last whorl. *Spire:* protoconch of one and one-half convex, smooth, glassy brown whorls; teleoconch of four or five whorls; suture linear, coronated by the axial ribs. *Sculpture:* last whorl with 12 keeled axial ribs, the interspaces of slightly lesser diameter and smooth. *Aperture:* narrow; outer lip thin and not apparently denticulate; fasciole grooved. *Color:* variable — horn to red-brown with a white spiral band about the periphery of the last whorl.

These dove shells are common at depths of 10 to 100 m.

S. smithi was described from Port Jackson, New South Wales.

Seminella virginea (Gould, 1860). Figs. 93 D; 94 N. (Synonyms: *Cythara varia* Pease, 1860, non *Columbella varia* Sowerby, 1832; *Columbella peasei* Martens and Langkavel, 1871, new name for *C. varia* Pease; *Zafra troglodytes* Souverbie, Watson, 1886.) Length, 3 mm; diameter, 1.5 mm. *Shell:* oval, attenuate at both ends; with keeled axial ribs; white with brown spirals or lineations. *Spire:* protoconch of two and one-half smooth white whorls; teleoconch of three somewhat inflated whorls; suture impressed. *Sculpture:* eight smooth axial ribs, the interspaces equal in diameter and smooth. *Color:* variable — white or ivory with light brown spirals undulating the axial

ribs or oblong brown splashes. *Animal:* tentacles and foot white with opaque white spots.

This is a common intertidal gastropod, found under rocks in tide pools, on solution benches, and shoreward on fringing reefs. The veliger larva is bilobed (J. B. Taylor, 1975). Beachworn shells are abundant in drift.

S. virginea was described from "the China Seas." This species appears to be distributed throughout the Indo-West Pacific, and is found under a variety of names in collections.

Additional Records

Shells tentatively identified as *Euplica livescens* (Reeve, 1859) (Fig. 94 M) have been found in beach drift on Midway. The shells are about 11 mm in length, smooth, colored dark pink but flushed with yellow and there are faint brown and white spots and axially oriented lines.

Columbella digitale Lesson, 1842a and *C. clathra* Lesson, 1842a were unfigured and are unidentified. *C. nodulosa* Nuttall, recorded in Jay's *Catalogue* (1839) is a *nomen nudum*.

Family **Colubrariidae**

The shells of the colubrarids are fusiform, with numerous convex whorls and discontinuous varices. The sculpture is of closely set spiral and axial ribs which become granular at their points of intersection. The aperture is rather small for the size of the shell and denticulate within; there is a short, open recurved canal. The protoconch is minute, of two rather depressed whorls; it is of a form associated with a free-swimming larval stage.

The systematic position of the Colubrariidae Dall 1904 has not been satisfactorily settled, and the family has been variously assigned to the Buccinacea (Schepman, 1913; Demond, 1957), the Fusidae (Iredale, 1929b), and the Cymatiidae (Kuroda and Habe, 1952; Thiele, 1929; Wenz, 1941). Ponder (1973) describes several anatomical features which separate some of the Colubrariidae from the rest of the Buccinacea: a thin, noninvaginable proboscis sac in which the retracted proboscis is convolute, a vestigal radula, a glandular mid-esophagus, and a long stomach. The minute radula and tiny mouth suggest some form of suctorial feeding with the muscular proboscis wall perhaps used as a pump.

Colubraria muricata (Lightfoot, 1786). Fig. 92 L. Length, 67 mm; diameter, 27 mm. *Shell:* fusiform, turreted, with straight sides; with small noduled axial ribs and spiral striae; cream with spiral bands of brown. *Spire:* high and pointed; whorls slightly inflated; suture impressed. *Sculpture:* axial rows of small, rough nodules and weak spiral threads. *Aperture:* outer lip with 10 to 15 denticles on the inner margin; parietal wall and columella with a thick callus, the columellar callus expanding to form a thick rim; columella smooth or with weak folds. *Color:* cream with pale brown spiral

bands and two or three interrupted lines of darker brown; aperture, outer lip and columella cream.

Specimens are rarely found at depths of 20 m.

This species is widely distributed in the Indo-West Pacific.

Colubraria obscura (Reeve, 1844). Fig. 92 N. (Synonym: *Colubraria muricata* (Humphreys), Tinker, 1958.) Length, 30 mm; diameter, 15 mm. *Shell:* fusiform, turreted; with straight sides; with fine axial ribs and spiral threads, slightly beaded at the junctions; fawn spirally banded with brown and with brown spots. *Spire:* acuminate; teleoconch of about eight slightly convex whorls; suture impressed. *Sculpture:* fine axial ribs and spiral threads lightly beaded at the junctions; about 11 irregularly arranged varices on the spire. *Aperture:* ovate; lirate within; columella thickly enameled. *Color:* fawn, lightly banded with brown and with a few square brown spots in spirals; varices spotted with brown.

Living animals are only occasionally found, at depths of about 10 m.

C. obscura was described from "the East Indies" and appears to be widespread within the Indo-West Pacific. Abbott (1974) reports it from Bermuda, Florida, and Brazil.

Colubraria tortuosa (Reeve, 1844). Fig. 92 M. (Synonyms: *Colubraria distorta* Sch. and Wag., Tinker, 1952; *?C. strepta* Cossmann, Tinker, 1952.) Length, 40 mm; diameter, 19 mm. *Shell:* fusiform, turreted; spire curiously twisted; with low, irregularly spaced varices and beaded spiral threads; fawn. *Spire:* twisted; teleoconch of ten or more inflated whorls; suture impressed. *Sculpture:* fine, low axial ribs not continuous over the suture and equally fine spirals of small nodules; axial ribs and their interspaces of equal diameter, the interspaces between the spiral threads two or three times the diameter of the spirals; each whorl with a bandlike varix, the varices irregularly spaced on the whorls. *Aperture:* oval; lirate within; outer lip flaring; outer lip, columella and parietal wall thickly enameled. *Color:* fawn, encircled with obsolete and irregularly spaced spirals of brown spots; aperture ivory white.

Living animals are only occasionally encountered in sand under coral blocks at depths of 10 m; beachworn shells are fairly common.

C. tortuosa occurs in the western Atlantic as well as throughout the Indo-West Pacific (Abbott, 1958, as *C. obscura*).

Family **Nassariidae**

The nassarids have more or less ovate shells with a high spire and short, recurved siphonal canal. A callus usually covers the inner lip, often spreading over the last whorl. The operculum is small, with the nucleus terminal.

Nassarids live mainly on soft substrate and have a large foot and long siphon; there are usually two short tentacles on the posterior end of the foot. These snails are carnivorous — drilling bivalves — and scavengers — feeding on decaying fish.

Nassarius crematus (Hinds, 1844). Fig. 95 F. (Synonym: *Nassa splendidula* Dunker, Bryan, 1915.) Length, 13 mm; diameter, 7 mm. *Shell:* ovate, inflated; with

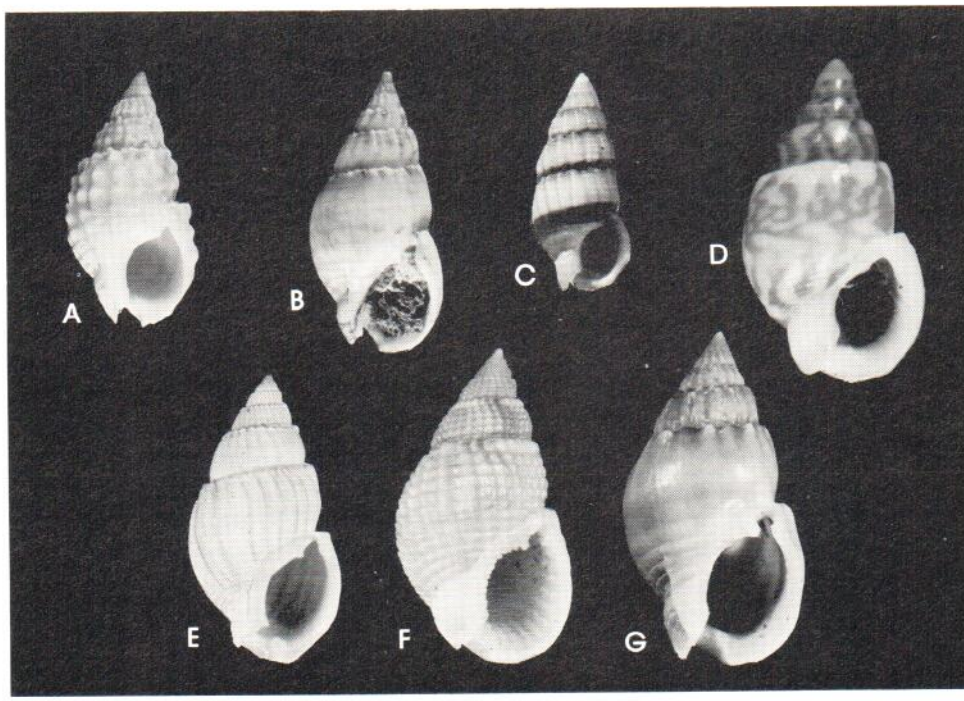


Figure 95.—**Nassariidae.** A. *Nassarius papillosus*, length 48 mm. B. *N. gaudiosus*, length 21 mm. C. *N. pauperus*, length 7 mm. D. *N. shackelfordi*, length 8 mm. E. *N. olomea*, length 16 mm (holotype). F. *N. crematus*, length 13 mm. G. *N. hirtus*, length 24 mm.

narrow, nodular axial ribs; white or cream. *Spire:* protoconch of two and one-half small shining, white whorls; teleoconch of five inflated, convex whorls; suture deeply channeled and occasionally coronate. *Sculpture:* narrow axial ribs cut into small nodules by shallow spiral grooves of approximately equal diameter; interspaces of ribs and grooves microscopically striate; a shallow groove below the suture demarcating the axial ribs. *Aperture:* ovate; lirate within; outer lip thin; columella with five or more plaits. *Color:* cream banded or splashed with light brown, occasionally almost white.

These nassarids are common at depths of from 20 to 100 m. The veliger larvae are seasonal, found in the plankton in Kaneohe Bay, Oahu, in August (J. B. Taylor, 1975). They metamorphose when two and three-quarters whorls are complete, at a length of 750 μm, and the newly metamorphosed animals feed on juvenile *Pinna* and *Crassostrea* in the laboratory (J. B. Taylor, 1975).

N. crematus was described from the Strait of Malacca and is also reported from Australia, Fiji, and southern Japan (Cernohorsky, 1972b). It appears to be found to depths of 10 m elsewhere (Cernohorsky, 1972b).

Nassarius gaudiosus (Hinds, 1844). Fig. 95 B. (Synonyms: *Alectrion graphiterus* Beck, Edmondson, 1933; *Nassarius reeveanus* (Dunker), Tinker, 1958.) Length, 21 mm; diameter, 9 mm. *Shell:* fusiform, slender; smooth; cream with spiral threads of dark brown and blotched with darker. *Spire:* protoconch of two and one-half smooth whorls; teleoconch of seven slightly convex whorls; suture linear and crenulate.

Sculpture: apical whorls axially ribbed, the ribs becoming obsolete on the later whorls and indicated only as sutural crenulations. *Aperture:* ovate; outer lip thin; columellar callus barely developed. *Color:* cream, spirally threaded with dark red-brown and irregularly blotched with darker.

These nassarids are common in sandy tide pools and shoreward on fringing reefs. They are especially active at night.

N. gaudiosus was described from the Strait of Malacca and ranges from the Cocos-Keeling Islands to Polynesia (Cernohorsky, 1972b).

Nassarius hirtus (Kiener, 1834). Fig. 95 G. Length, 24 mm; diameter, 12 mm. *Shell:* ovate, solid; with smooth axial ribs and crenulate suture; flesh to fawn. *Spire:* protoconch of two smooth, pink whorls; teleoconch of five to six convex whorls; suture channeled. *Sculpture:* apical whorls ribbed and noduled; on later whorls suture coronated by sharp nodules; remainder of whorls with smooth, narrow, straight axial ribs becoming obsolete on the last whorl, the interspaces of slightly greater diameter and smooth. *Aperture:* broadly ovate; lirate within; outer lip barely thickened; columella callused. *Color:* flesh to tan, the apex usually darker; aperture white. *Animal:* pale yellow with black spots.

This species is found in shallow water and is fairly common in sandy areas on fringing reefs.

The type locality of *N. hirtus* was cited as New Holland and Tongatabu, but Cernohorsky (1972b) suggests this is an error and that this species is endemic to the Hawaiian Islands.

Nassarius olomea Kay, new species. Fig. 95 E. Length, 16 mm; diameter, 8 mm. *Shell:* conic-ovate; coronate at the suture and with slender, raised ribs between which are depressed spiral threads; cream, ribs brown. *Spire:* protoconch of three conical whorls, the abapical whorls with a minute peripheral keel; teleoconch of five convex whorls; suture deep, nodular. *Sculpture:* axial sculpture of narrow, raised, uniform ribs (22 on the last whorl), the interspaces wider than the ribs and crossed by sharp, depressed threads; a conspicuous subsutural groove cuts the ribs and makes them nodular at the suture. *Aperture:* ovate; outer lip thick and with numerous denticles; the basal denticle toothlike; columella and parietal wall coated with enamel; siphonal canal short; distinct. *Color:* cream, axial ribs brown.

These nassarids are common at depths of from 50 to 100 m.

Type locality: Mamala Bay, Oahu. *Holotype:* Bernice P. Bishop Museum No. 9802. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

This species is described, despite the plethora of names introduced for species of Nassariidae, and despite the well-known variability of species in the family. With these facts in mind, I have been unable to equate any species thus far described with the Hawaiian shells. They perhaps most closely resemble some shells of *N. siquijorensis* (A. Adams, 1852) (= *N. crematus* (Hinds, 1844) *fide* Cernohorsky (1972b)) and those of *N. ovoidea* Schepman, 1911. They are distinguished from the former by the lack of nodules on the ribs and depressed spiral threads and from the latter by their smaller size and less prominent spiral threads. Cernohorsky (1978b) indicated they represented *N. crebricostatus* Schepman, 1911 from the Sulu Sea but their larger size,

conic-ovate shape rather than oblong-ovate shape, cream color and brown ribs, and six-whorled teleoconch distinguish them. The distinctive characters are, however, the light, thin shells, lack of callus, and the fine spiral striae between the ribs. Derivation of name: *olomea,* Hawaiian — brown with darker stripes or spots. Refers to the cream-colored shell with brown ribs.

Nassarius papillosus (Linnaeus, 1758). Fig. 95 A. Length, 48 mm; diameter, 20 mm. *Shell:* ovate, heavy; polished; with prominent nodular axial ribs, suture coronate; tan to darker brown. *Spire:* protoconch of two and one-half glistening pink whorls; teleoconch of six to seven convex whorls; suture channeled and coronate. *Sculpture:* narrow axial ribs studded with small, sharp nodules, the interspaces smooth and of approximately equal diameter; base of last whorl striate. *Aperture:* broadly ovate; lirate within, outer lip thin, sharply dentate; columella callused. *Color:* flesh or tan blotched with darker; aperture white.

This species is common at depths of 10 to 20 m in pockets of coarse gravel.

N. papillosus is a well-known species throughout the Indo-West Pacific, from Mauritius to the Philippines and Polynesia.

Nassarius pauperus (Gould, 1850). Fig. 95 C. (Synonym: *Nassa microstoma* Pease, 1860.) Length, 7 mm; diameter, 3.5 mm. *Shell:* fusiform-ovate, solid; axial ribs crossed by coarse spiral cords; cream spirally banded with light brown. *Spire:* protoconch of two opaque white, mamillate whorls; teleoconch of five convex, inflated whorls; suture deeply channeled. *Sculpture:* broad axial ribs, the interspaces subequal; ribs and interspaces crossed by coarse spiral cords; base with a wide, shallow spiral groove; fasciole with spiral threads. *Aperture:* subcircular; outer lip denticulate in adult shells; columella callused and variously wrinkled. *Color:* cream, occasionally spirally banded with light brown.

This species occurs at depths of from 10 to 200 m. Beachworn specimens are occasionally found in drift.

N. pauperus is apparently restricted in its distribution to the Pacific Basin (Cernohorsky, 1972b).

Nassarius shackelfordi Melvill and Standen, 1896. Fig. 95 D. Length, 8 mm; diameter, 4 mm. *Shell:* ovate, solid; smooth; glossy, cream splashed with brown. *Spire:* protoconch of three and one-half whorls, apical whorls smooth, two abapical whorls with a spiral keel; teleoconch of about five convex, inflated whorls; suture channeled. *Sculpture:* microscopic growth striae and occasional fine spiral striae near the base. *Aperture:* broadly ovate; columella not callused; outer lip backed by a varix; lirate within. *Color:* glossy, cream with axially oriented flamelike brown marks.

These nassarids are rare, dredged at depths of 200 m.

N. shackelfordi was described from Lifu, Loyalty Islands.

Additional Records

Nassa cooperi Forbes, 1852, and *N. woodwardi* Forbes, 1852, were erroneously described from the Hawaiian Islands. *Buccinum plicatulum* Nuttall, in Jay's *Catalogue*

(1839) is a *nomen nudum*. *Nassa albescens* Reeve was recorded from the "Sandwich Islands" by Pease *fide* Smith (1878). *Nassarius globosus* (Quoy and Gaimard, 1833) was recorded from Hawaii by Cernohorsky (1972b) but I have seen no authentic records of Hawaiian shells.

Family **Fasciolariidae**

The shells of the fasciolarids are fusiform, often with long, drawn-out siphonal canals, and there is an oval, horny operculum. The columella in *Peristernia* and *Latirus* is plicate, but in *Fusinus* it is smooth its entire length and the fusinids are sometimes separated in the family Fusinidae.

Fasciolarids are distinguished by a conspicuously red-pigmented animal, and the radula is distinctive with multicuspid lateral teeth and small central teeth. A planktonic veliger larval stage has been reported in *Latirus nodatus* (J. B. Taylor, 1975), and the protoconchs of *Fusolatirus kuroseanus*, *Peristernia squamosus*, and *P. ustulata* are of the type associated with a free-swimming life history. In *Peristernia chlorostoma* development is direct (J. B. Taylor, 1967), and the protoconch of *Fusinus sandvicensis* is of a type associated with direct development.

Dolicholatirus acus (Adams and Reeve, 1850). Fig. 96 D. Length, 13 mm; diameter, 4 mm; aperture and canal, 7 mm. *Shell:* spindlelike, slender, aperture and siphonal canal longer than spire; with broad axial ribs crossed by spiral cords; yellow, spirally banded with brown at the suture and on the base. *Spire:* protoconch of three and one-half conical whorls, apical one and one-half whorls microscopically spirally striate, abapical whorls with beaded axial riblets; teleoconch of eight slightly inflated whorls; suture shallow, encircled with a spiral thread. *Sculpture:* broad axial ribs, six on the last whorl, absent on the base; interspaces of lesser diameter than the ribs; ribs and interspaces crossed by flat-topped spiral cords and nearly flat-bottomed grooves; suture encircled by a beaded spiral cord; base with three beaded cords. *Aperture:* narrow, with the canal longer than the spire; outer lip thin; columella with two folds. *Color:* golden yellow, spirally banded with dark brown at the suture and on the base.

This shell is rarely found, occurring at depths of 200 m.

D. acus was described from the South China Sea off Borneo and has been reported from Japan and the Miocene of the Ryukyu Islands (MacNeil, 1960).

Fusinus nicobaricus (Röding, 1798). Fig. 96 K. (Synonyms: *Fusus novae-hollandiae* Reeve, Bryan, 1915; *F. undatus* Gmelin, Tinker, 1958.) Length, 132 mm; diameter, 53 mm. *Shell:* fusiform, solid; with bold axial ribs noduled at the shoulders; white to cream. *Spire:* attenuate; teleoconch of six inflated whorls; suture impressed. *Sculpture:* apical whorls with axial ribs, the abapical whorls with prominent nodules at the shoulders and often with smaller nodes between; spiral sculpture of thick spiral threads interspaced with finer threads. *Aperture:* ovate; lirate within; siphonal canal long and thick; columella smooth. *Color:* white or cream, sometimes splashed with brown. *Animal:* body and foot red-orange (McDowall, 1974).

These shells are rarely found, occurring at depths of from 30 to 150 m. They are

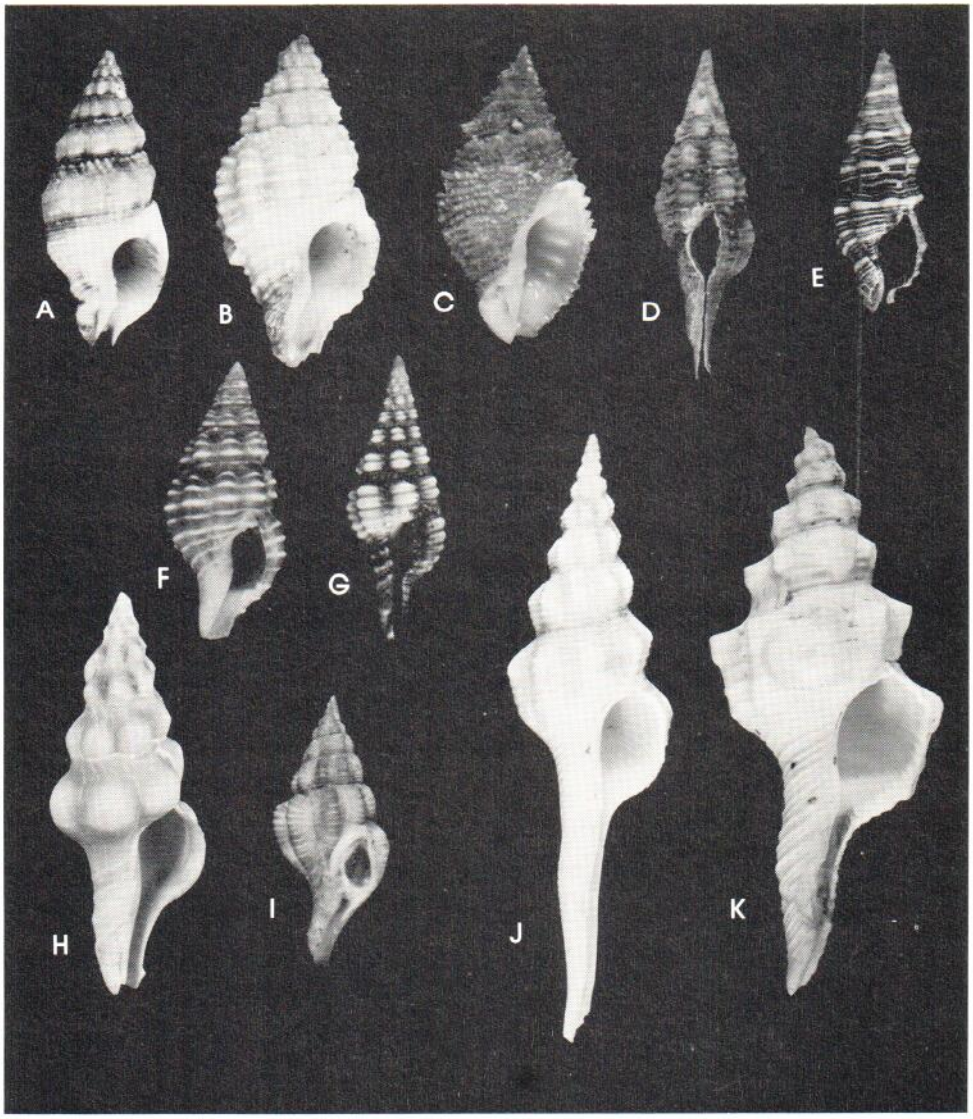


Figure 96.—**Fasciolariidae.** A. *Peristernia chlorostoma*, length 17 mm. B. *P. ustulata*, length 22 mm. C. *P. squamosa*, length 19 mm. D. *Dolicholatirus acus*, length 13 mm. E. *Latirus noumeensis*, length 13 mm. F. *Cantharus pulcher*, length 18 mm. G. *Latirus caledonica*, length 20 mm. H. *L. nodatus*, length 83 mm. I. *Fusolatirus kuroseanus*, length 27 mm. J. *Fusinus sandvicensis*, length 40 mm. K. *F. nicobaricus*, length 132 mm.

not uncommon in beach drift in the leeward islands. One specimen was found feeding on *Pinna* at a depth of 30 m off Koloa Landing, Kauai (McDowall, 1974).

F. nicobaricus ranges from Queensland, Australia, to Polynesia. Elsewhere in its range the shells are ornamented with axial lines and streaks of red-brown. Although this species is often referred to *F. undatus* Gmelin, the heavier axial sculpture and less attenuate spire would seem to distinguish it.

Fusinus sandvicensis (Sowerby, 1880). Fig. 96 J. (Synonym: *Fusinus undatus* (Gmelin), Tinker, 1952.) Length, 40 mm; diameter, 11 mm. *Shell:* fusiform, slender; with rounded axial ribs and spiral threads; white. *Spire:* protoconch of one and one-half mammillate whorls; teleoconch of about ten slightly inflated whorls, the apical whorls turreted, the remaining whorls sloping at the shoulders; suture shallow. *Sculpture:* blunt, obscurely noduled axial ribs, the interspaces of lesser diameter than the ribs and crossed by spiral carina of varying sizes. *Aperture:* ovate; lirate within; siphonal canal long and slender; columella smooth. *Color:* white; periostracum brown.

These spindle shells are common in dredge hauls at depths of from 50 to 150 m.

F. sandvicensis was described from the Hawaiian Islands. The shells are distinguished from those of *F. nicobaricus* by their smaller size and slender form.

Fusolatirus kuroseanus Okutani, 1975. Fig. 96 I. Length, 27 mm; diameter, 11 mm. *Shell:* fusiform; with bold axial ribs crossed by spiral cords; white with brown ribs. *Spire:* protoconch of three and one-half conical white whorls, the abapical whorl with curved axial riblets; teleoconch of eight inflated whorls; suture impressed. *Sculpture:* bold axial ribs crossed by spiral cords and weaker interstitial threads, the spiral sculpture stronger on the ribs than in the interspaces. *Aperture:* ovate; outer lip thin and sharp; columella with two ill-defined folds; siphonal canal narrow, recurved; operculum horny, red-brown. *Color:* cream, axial ribs brown.

These fasciolarids are uncommon, dredged at depths of 100 to 300 m.

F. kuroseanus was described from a submarine bank near Hachijo Island, Japan, at a depth of 260 m.

Latirus sp. cf. *caledonica* (Petit, 1851b). Fig. 96 G. Length, 23 mm; diameter, 4 mm; aperture length, 6.8 mm. *Shell:* fusiform; with bold axial ribs and thick spiral cords; dark brown spirally banded with golden yellow. *Spire:* protoconch of three and one-quarter conical, brown whorls, the apical one and one-quarter whorls smooth, the others with axial riblets; teleoconch of eight whorls; suture shallow, marked by a beaded cord. *Sculpture:* six bold axial ribs on a last whorl 4 mm in diameter, the interspaces of lesser diameter than the ribs and deep; spirally banded with thick cords, the interspaces between the cords about the same diameter as the cords and with axial striae; suture with a beaded cord and with three beaded cords on the base. *Aperture:* ovate; outer lip thin, smooth within; columella with two prominent, oblique plaits. *Color:* dark brown, spiral cords golden yellow.

These shells are rare at depths of 200 m.

L. caledonica was described from New Caledonia.

Latirus nodatus (Gmelin, 1791). Fig. 96 H. (Synonym: *Latirus nodus* Martyn, Edmondson, 1933.) Length, 83 mm; diameter, 35 mm. *Shell:* fusiform, solid; with massive axial ribs and nodules; yellow brown, aperture pink. *Spire:* protoconch of three and one-quarter conical, pink whorls; teleoconch whorls barely convex; suture impressed. *Sculpture:* low, rounded tubercles forming massive axial ribs which extend only part way down each whorl. *Aperture:* ovate; outer lip thin and lightly fluted; lirate within; columella with four strong plaits. *Color:* light brown to yellow; aperture pink. Periostracum thick, brown.

These fasciolarids occur on hard substrates at depths of 8 to 24 m in the windward islands and on the reef flat at French Frigate Shoals.

L. nodatus is apparently limited in its distribution to the tropical Pacific.

Latirus noumeensis (Crosse, 1870b). Fig 96 E. Length, 13.5 mm; diameter, 5 mm; aperture and canal, 5 mm. *Shell:* bluntly fusiform; with thick axial ribs crossed by spiral cords; black, spirally banded with golden yellow and white. *Spire:* teleoconch of seven slightly convex whorls; suture shallow and with a spiral cord. *Sculpture:* broad, round axial ribs, eight on the last whorl, the interspaces of lesser diameter than the ribs; spiral sculpture of fine threads with one larger cord on each whorl. *Aperture:* ovate, broad; outer lip thin; parietal callus upstanding on the columella; columella with two plaits. *Color:* black, with five golden yellow cords on the last whorl, two on the apical whorls, the yellow cords separated by two or three white spiral threads.

These fasciolarids are found at depths of from 23 to 36 m.

L. noumeensis was described from New Caledonia and also occurs in Mauritius (Tapparone Canefri, 1880) and Japan (Habe, 1961a).

Peristernia chlorostoma (Sowerby, 1825). Figs. 96 A; 97. (Synonyms: *Turbinella pacifica* Lesson, 1842b; *Latirus newcombi* A. Adams, 1855b; *L. stigmaria* A. Adams, 1855b; *L. xanthostoma* Nuttall, *nomen nudum; Peristernia selinae* Melvill, 1891; *P. xanthostigma* Dall, *nomen nudum,* Mant, 1923.) Length, 17 mm; diameter, 9 mm. *Shell:* fusiform-ovate; whorls convex; with broad axial ribs crossed by fine spiral threads; cream, spirally banded with dark brown, tip of canal brown. *Spire:* protoconch usually decollate; teleoconch of six or eight convex whorls, the last whorl inflated at the periphery; suture channeled. *Sculpture:* broad, convex, rather irregular axial ribs, the interspaces subequal and deep; spiral sculpture of irregularly spaced threads and cords overriding the axials; suture crenulate with two rows of sharp nodules. *Aperture:* broadly ovate; outer lip thin; lirate within; columella twisted, with three plaits, the apical two the largest. *Color:* variable — cream to yellow-brown, spirally banded or spotted with darker brown at the suture and peripherally on the last whorl, tip of fasciole dark brown; aperture white or yellow. Some specimens are almost entirely brown, others almost white. *Animal:* exposed parts and sole of foot vermilion, upper portions of foot and neck peppered with black.

These gastropods are among the most abundantly occurring of shallow-water gastropods in the Hawaiian Islands, found under rocks in tide pools and in shallow waters shoreward of fringing reefs, and on benches.

P. chlorostoma produces clusters of small (2 mm in height) vase-shaped egg-capsules containing from 1 to 4 pink eggs. The young metamorphose in the capsule and emerge through a hole in the top as minute, juvenile shells (J. B. Taylor, 1967).

An extremely variable species, as is reflected in the number of names which have been applied to it, *Peristernia chlorostoma* may be limited in its distribution to the Hawaiian Islands, although a number of species that occur elsewhere in the Indo-West Pacific resemble it. While no single character distinguishes the Hawaiian shells, a combination of characters appears to be unique: smaller size, more convex whorls, and spotted or banded color pattern distinguish the Hawaiian specimens from *P. crocea*

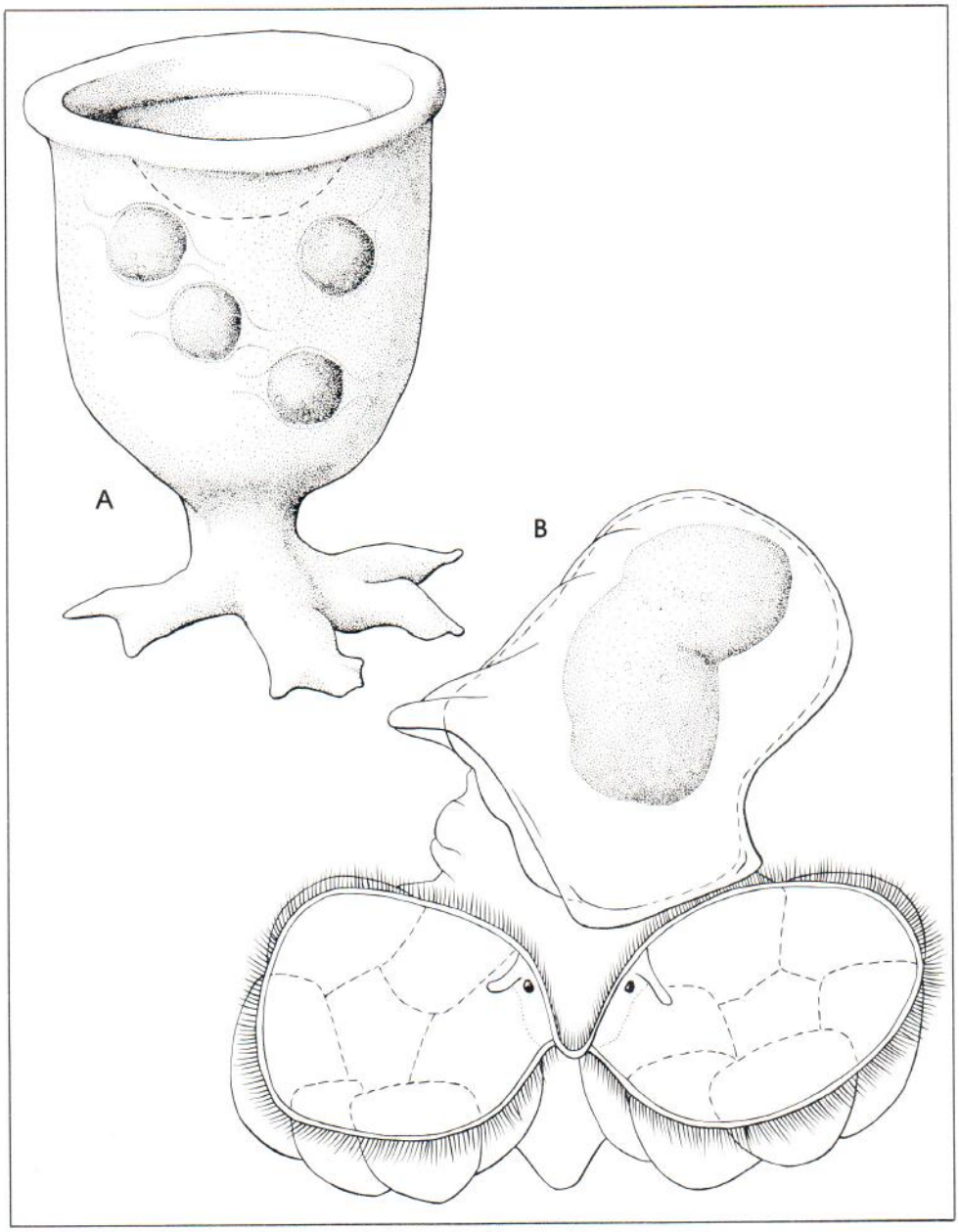


Figure 97.—**Fasciolariidae.** *Peristernia chlorostoma*. A. Egg mass, lateral view. B. Veliger, 29 days. (After Taylor, 1967.)

(Gray, 1839), *P. marquesana* (A. Adams, 1855b), and *P. ustulata* (Reeve, 1847). *P. chlorostoma* was described by Sowerby (1825) in the *Tankerville Catalogue* without a locale, but shells of the species in the British Museum (Natural History) from the Tankerville Collection are comparable with recently collected Hawaiian shells.

Peristernia squamosa (Pease, 1863a). Fig. 96 C. Length, 19 mm; diameter, 10 mm. *Shell:* shortly fusiform; with axial ribs and spinose, imbricated spiral threads; gray-white. *Spire:* protoconch of about three small, conical whorls; teleoconch of five slightly inflated whorls; suture appressed. *Sculpture:* somewhat obscure axial ribs which are spinose at the shoulder and prominent spiral sculpture of imbricated threads, some of them becoming spinose. *Aperture:* narrow; with four or five lirations; sulcate near the suture with a feeble subsutural callus; outer lip sharp-edged, crenulate; columella with three or more folds. *Color:* white or cream, with a tendency toward red-brown on the prominences; aperture white.

These shells are common in dredge hauls at depths of 96 to 350 m.

P. squamosa was described from Tahiti, and is common throughout the Pacific.

Peristernia ustulata (Reeve, 1847). Fig. 96 B. Length, 22 mm; diameter, 10 mm. *Shell:* fusiform-ovate; with coarse axial ribs and prominent spiral cords; cream, siphonal canal dark purple-brown. *Spire:* teleoconch of five or six convex whorls; suture impressed. *Sculpture:* coarse axial ribs, the interspaces of slightly greater diameter than the ribs; ribs and interspaces crossed by scabrous spiral cords. *Aperture:* ovate; lirate within; outer lip convex, constricted basally, crenulate on the edge; columella with a callus and two or three folds; siphonal canal moderately short and recurved. *Color:* cream to light brown, the siphonal canal and the apex purple-brown; aperture cream-white, often with an orange tint.

These fasciolarids are rare, dredged at depths of more than 20 m.

P. ustulata is common in the tropical Pacific, where it is found in shallow water.

Additional Records

Latirulus fasciatus Habe and Okutani, 1968, was described from shells dredged at depths of 400 to 480 m off Midway. The shells are solid, stout, elongate-fusiform, 32 to 40 mm in height and 14.3 to 16.9 mm in diameter, with four or five raised, bright brownish cords on the whorls. They resemble those of *Latirulus turritus* Gmelin, a well-known intertidal species in the tropical Central Pacific. Shells of *Latirus craticulatus* (Linnaeus, 1758) are recorded from Honolulu Harbor dredge spoils and one or two have been found by SCUBA divers.

Superfamily VOLUTACEA

Of the six families in the Volutacea — Marginellidae, Harpidae, Olividae, Volutidae, Cancellariidae, and Vasidae — only the first three are found in the Hawaiian Islands. The group is possibly an unnatural one, with a variety of anatomical features. In most the columella has more or less well-developed folds. The radula is rachiglossate but in some forms is reduced from the normal three teeth per transverse row to one sharply tricuspid tooth. Many of the tropical Volutacea, such as the harps and olives, burrow in sand.

Family **Olividae**

The olives have brilliantly polished, solid, cylindrical shells with a long aperture and a channeled suture on the low spire. There is a narrow callus over the columellar area which is wrinkled or folded into plaits. The aperture is narrow and long, with an anterior notch.

Most olives are sand-dwellers, plowing through the sand just beneath the surface and leaving a characteristic trail. The foot is greatly developed, and anterior and lateral flaps sometimes enclose the shell completely. In some forms the propodium is used as a swimming organ (Wilson, 1969). The eyes are reduced or absent. Olives are carnivores, feeding on small crustaceans.

Oliva paxillus sandwicensis Pease, 1860. Fig. 98 D. Length, 25 mm; diameter, 13 mm; aperture length, 19 mm. *Shell:* cylindrical, solid; with columellar folds; freckled brown and blotched with white. *Spire:* acuminate, of three whorls; suture channeled. *Sculpture:* none obvious, shell smooth and polished. *Aperture:* two-thirds the length of the shell; outer lip thickened internally; columella with two or three folds. *Color:* minutely freckled and blotched with white, red-brown and darker brown, darker abapically than at the spire; apex white; aperture white with two broad, equidistant dark brown bands on the interior.

These olives are common in coarse sand pockets in subtidal coral communities at depths of about 10 m. The animals are very active and may extrude a purple dye when disturbed. A strong odor is often associated with them.

The shells of the Hawaiian subspecies are distinguished by their stouter form, less projecting spire, and darker color than those of the widely distributed Indo-West Pacific species, *O. paxillus* Reeve, 1850.

Oliva richerti Kay, new species. Fig. 98 G, H. Length, 31 mm; diameter, 13 mm (holotype). *Shell:* oblong-cylindrical, spire acuminate; smooth and glossy; cream with spirals of tentlike marks of red-brown. *Spire:* protoconch of three and one-half bulbous whorls; protoconch of three whorls, the last the largest; suture barely channeled. *Sculpture:* axial growth striae only. *Aperture:* narrow; columella with four prominent plaits. *Color:* cream white with lateral V-shaped marks of red-brown, brown blotches beneath the suture and with brown bands or spots encircling the base; columella and aperture white.

These olives are rare, dredged at depths of about 200 m.

Type locality: Mamala Bay, Oahu, depth of 200 m. *Holotype:* Bernice P. Bishop Museum No. 9804.

These shells are rather like those of *O. multiplicata* Reeve, 1850, but are smaller, wider proportionately to their length and the columellar plaits are not "fine." This species is named for Dr. Thomas Richert who participated in the *Pele* expeditions which resulted in finding these olives.

Olivella apicalis Kay, new species. Fig. 98 E, F. Length, 7 mm; diameter, 3 mm. *Shell:* bluntly fusiform, slender; smooth; translucent white banded with brown. *Spire:* protoconch of three blunt, brown whorls; teleoconch of about five whorls, the

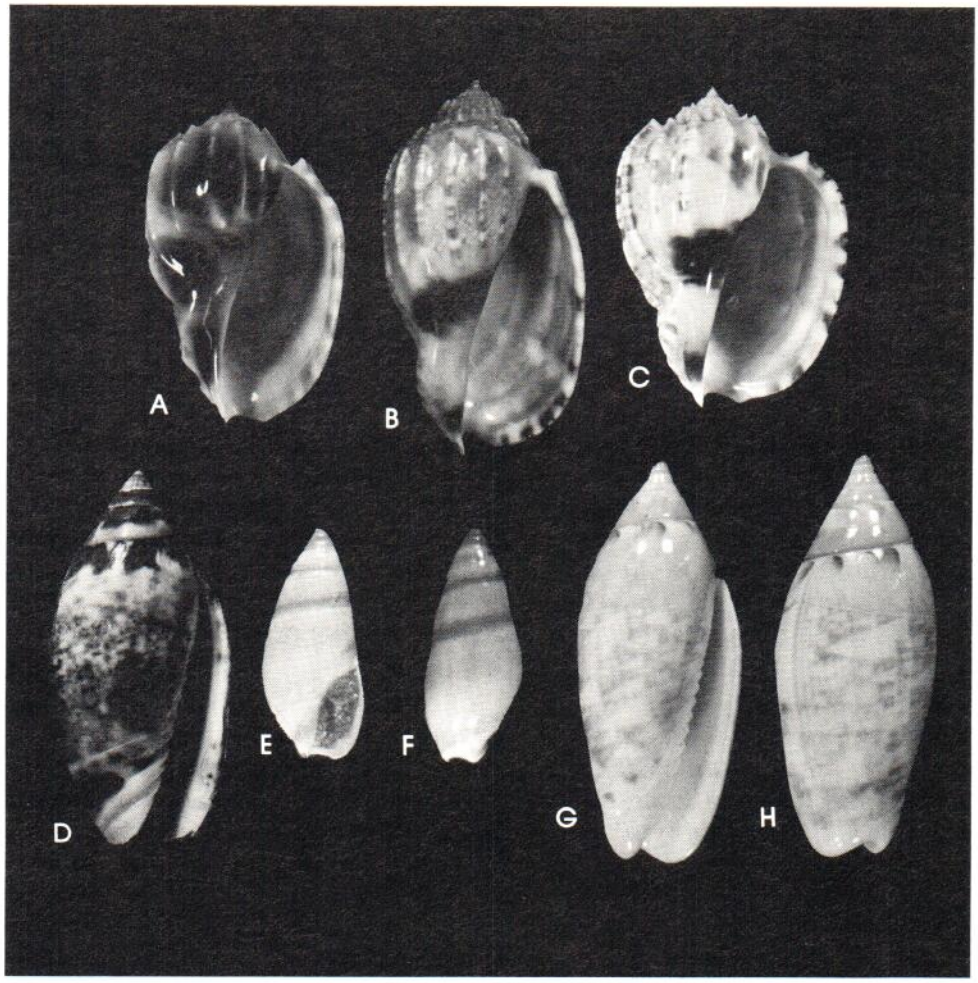


Figure 98.—A. *Harpa major*, length 49 mm. B. *H. amouretta*, length 34 mm. C. *H. harpa*, length 55 mm. *D. Oliva paxillus sandwicensis*, length 25 mm. E, F. *Olivella apicalis*, length 7 mm (holotype). G, H. *Oliva richerti*, length 31 mm (holotype).

last comprising more than half the length of the spire; suture obscure. *Sculpture:* surface smooth and polished. *Aperture:* narrow; outer lip thin, slightly arcuate; inner lip with a wash of callus; columella short, with a strong plication near the anterior end and two or three small spiral threads above it. *Color:* translucent white or cream with a pale brownish band above and another below the periphery; protoconch brown.

These small olivellas are common in dredge hauls at depths of from 500 to 700 m.

Type locality: Mamala Bay, Oahu, depth of 502 m. *Holotype:* Bernice P. Bishop Museum No. 9806.

These shells are distinguished from other olivellas by their small size, compact form, and deep habit.

Family **Harpidae**

The harps are among the most beautiful of all shells with shiny surfaces which are raised into axial ribs suggestive of the strings of the musical instrument. The shells are medium to large in size, globose, with an inflated last whorl, and they are variegated with red-brown and pink. The aperture is broadly ovate with a thickened outer lip and a wide anterior notch. The parietal and columellar areas of the aperture are covered by a callus. There is no operculum.

These gastropods are sand burrowers and have a large, fleshy foot divided into two parts. The posterior portion (metapodium) is sometimes autotomized (self-amputated) when the animals are disturbed. These gastropods feed on crabs and shrimps, apparently enclosing the prey in a coat of mucus, removing the soft parts and discarding the carapace (Chabouis and Chabouis in Rehder, 1973).

Harpa amouretta Röding, 1798. Fig. 98 B. Length, 34 mm; diameter, 20 mm. *Shell:* ovate; axially ribbed; yellow-white variegated with purple-brown. *Spire:* protoconch of four or five conical pink whorls, each with a basal keel; teleoconch of four angulately shouldered whorls. *Sculpture:* sinuous axial ribs extending from the apex to the lip, the ribs subspinose at the shoulder of the whorls. *Aperture:* ovate; outer lip thin; columella straight and glazed. *Color:* yellow-white to dark straw, marked in the intercostal spaces with varying shades of brown in zigzag lines, the ribs with pairs of fine spiral lines.

Specimens are rarely found, recorded at depths of from 20 to 40 m.

H. amouretta is distributed throughout the Indo-West Pacific from the Red Sea and East Africa to the Marquesas. Elsewhere in its range these gastropods are found on reef flats at depths of less than 1 m (Rehder, 1973).

Harpa harpa (Linnaeus, 1758). Fig. 98 C. Length, 55 mm; diameter, 40 mm. *Shell:* broadly ovate; axially ribbed; variegated red-brown with three separated chestnut blotches on the ventral side. *Spire:* protoconch of three to three and one-half conical, pink whorls; teleoconch of three angulated, shouldered whorls, last whorl bluntly angulate below the shoulder. *Sculpture:* low, distant, slightly curved axial ribs, the interspaces axially striate; shoulder with strong spines on the ribs. *Aperture:* large, ovate; outer lip gently curved, thickened; ventral surface thinly glazed. *Color:* pink-brown, patterned with brown and white and with the ribs marked by groups of spiral lines, a spiral band of darker rust-brown and irregular spots on the middle of the last whorl in every other interspace; ventral surface with three chestnut spots.

These harp shells are very rarely found in Hawaii, known only from crabbed shells found at depths of 40 m.

H. harpa is found throughout the Indo-West Pacific, but shells are rare in the Indian Ocean and most abundant in the Philippines and Indonesia (Rehder, 1973).

Harpa major Röding, 1798. Fig. 98 A. (Synonym: *Harpa conoidalis* Lamarck, Tinker, 1952.) Length, 49 mm; diameter, 34 mm. *Shell:* broadly ovate, heavy; axially ribbed with wide cords; pink with brown flamelike markings and a large chestnut brown blotch on the ventral surface. *Spire:* protoconch of three and three-quarters to

four glassy, flesh-colored whorls; teleoconch of six whorls. *Sculpture:* sinuous axial cords prominently and subspinosely angulate; interspaces axially striate. *Aperture:* large, ovate; outer lip simple; columella straight; parietal wall and columella glazed. *Color:* pink-flesh to red-brown patterned with pink and white between the axial ribs and with a large chestnut brown blotch extending over most of the columellar area.

These harps occur in flat, sandy areas at depths of from seven to 20 m. They have been noted to disgorge small shrimps (Weaver, 1963b).

H. major is widely distributed in the Indo-West Pacific. Elsewhere in their range these harps are found on reef flats at depths of less than 1 m (Rehder, 1973).

Family **Marginellidae**

The marginellids have smooth, glossy shells with a thickened outer lip, large last whorl, and long, narrow aperture. There is a series of strong folds on the abapical part of the columella.

These prosobranchs live from the rocky intertidal to depths of several hundred meters. Little is known of their anatomy or habits. The long siphon, rachiglossan radula of central teeth only, gland of Leiblein, and other features of their anatomy suggest a carnivorous habit, but in some forms there is no buccal mass and feeding is presumably suctorial (Ponder, 1970). The sexes are separate, and the egg capsules which have been described are lens-shaped, each with a single egg (Knudsen, 1950; Ponder, 1970). The protoconch is paucispiral, indicating that development in some species may be direct.

While certain areas of the world, notably the coasts of western Africa and Australia, have produced remarkable numbers of marginellids, with shells up to 40 mm in length and some with bright colors, relatively few species are found in the Indo-West Pacific, and most are small (less than 10 mm) and white. These small, white shells are difficult to group into generic units because of their overall similarity, although anatomical studies indicate several divisions within the group. Subtle differences in shape cause problems in species identification.

The four genera recognized here may be keyed as follows (adapted from Keen, 1971):

1. Spire low to concealed 2
   Spire about half the length of the shell ..... *Dentimargo*

2. Aperture with anterior end rounded 3
   Aperture with a distinct anterior notch ..... *Granula*

3. Shell ovate 4
   Shell cylindrical, often arcuate ..... *Volvarina*

4. Outer lip smooth within; spire low, not concealed by outer lip ..... *Cysticus*
   Outer lip denticulate within, posterior end concealing spire ..... *Granulina*

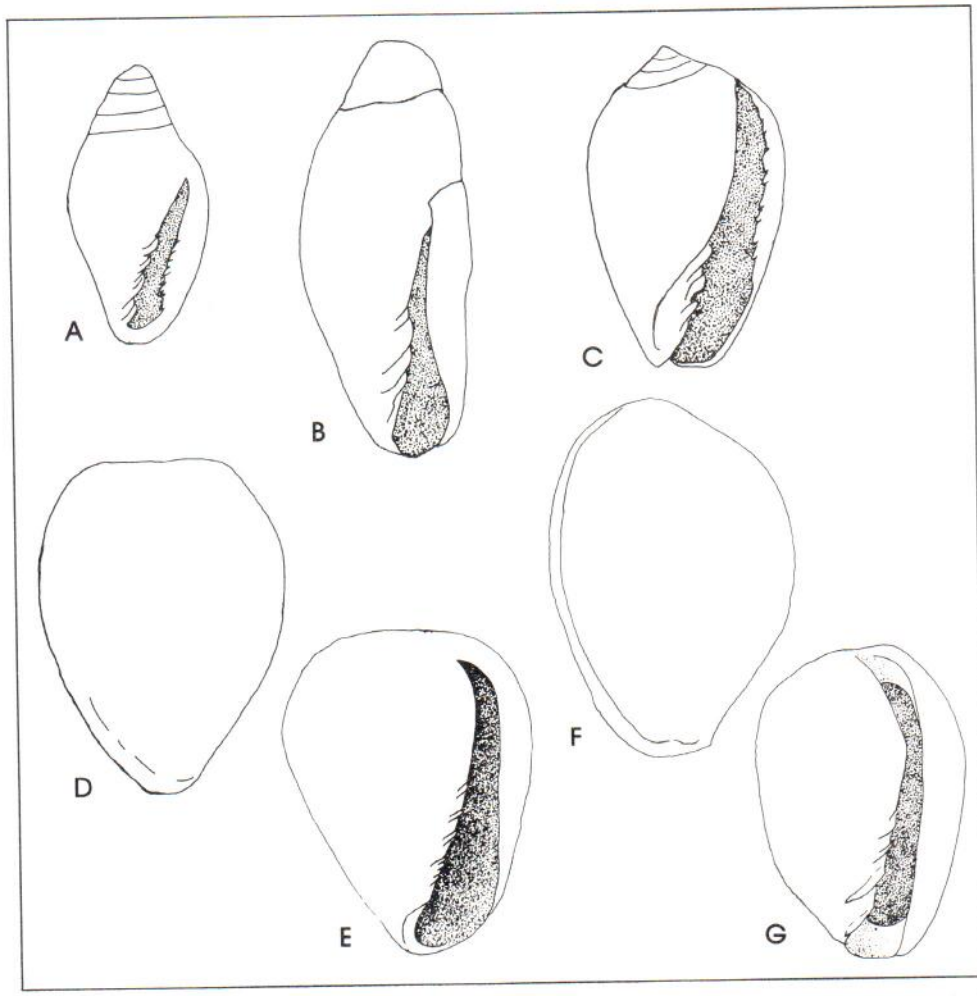


Figure 99.—**Marginellidae.** A. *Dentimargo pumila,* length 5 mm. B. *Volvarina fusiformis,* length 3 mm. C. *Granula sandwicensis,* length 2.5 mm. D, E. *Cysticus huna,* length 1.75 mm. F, G. *Granulina vitrea,* length 1 mm.

Cysticus huna Kay, new species. Fig. 99 D, E. Length, 1.75 mm; diameter, 1 mm (holotype). *Shell:* pyriform, broad and humped at the shoulder, flattened on the spire; glossy, translucent white. *Spire:* apex flat, spire completely immersed, covered by callus. *Sculpture:* microscopic growth striae only. *Aperture:* narrow apically, wider at the base; outer lip nearly as long as the spire, thick, smooth within; columella with four to six strong, oblique folds. *Color:* glossy, translucent white.

These marginellids are uncommon, found in tide pools and to depths of about 50 m. Shells of *Granulina vitrea,* which are about the same size as those of this species, outnumber these shells by more than 10 to 1 in sediments.

Type locality: Barbers Point, Oahu, from a depth of 50 m. *Holotype:* B. P. Bishop Museum No. 96827. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

Shells of *C. huna* are distinguished from those of *Granulina vitrea* (Laseron, 1957) from Australia by the smooth outer lip and distinctly pyriform shape. They are distinguished from the shells of *Euliginella angasi* (Crosse, 1870) from Australia by the broader shoulder proportionate to the length of the shell and the lack of a parietal callus. Derivation of name: *huna,* Hawaiian — minute particle. Refers to the small size of these shells.

Dentimargo pumila (Redfield, 1869). Fig. 99 A. (Synonym: *Marginella acaria* "Dall," Mant, 1923, *nomen nudum*.) Length, 5 mm; diameter, 2.5 mm. *Shell:* biconic, rather wide at the shoulder, spire projecting; polished white. *Spire:* four or five whorls; suture obscured by enamel. *Sculpture:* growth striae only. *Aperture:* evenly open, with a posterior notch, about one-fourth the length of the spire; outer lip moderately thick, denticulate; columella with four folds of about the same size, the apical folds transverse. *Color:* white. *Animal:* mantle, proboscis and foot transparent white; mantle smooth; anterior end of foot deeply cleft medially and bilabiate.

This is the most uncommon of the Hawaiian marginellids, found only occasionally in tide pools and on reefs.

D. pumila was described from Mauritius (as *Marginella pusilla* H. Adams, 1862, non F. E. Edwards, 1856).

Granula sandwicensis (Pease, 1860). Fig. 99 C. (Synonyms: *Marginella sandwichensis* Pease, Weinkauff, 1879; *Marginella oryza* Pease, 1860, non Lamarck, 1822; *M. debilis* Pease, 1871d, non Lamarck, 1822; *Granula aquaegutta* Jousseaume, 1875.) Length, 2.5 mm; diameter, 1.5 mm. *Shell:* conic, solid; polished white. *Spire:* blunt; left margin gently rounded. *Sculpture:* occasionally with axial striae. *Aperture:* narrow; outer lip curving inward and with minute denticulations on the inner edge; parietal region with a thin callus; columella with two to four oblique folds of about the same size. *Color:* white. *Animal:* white with black blotches showing through the transparent shell.

These marginellids are common on the undersurfaces of algal-covered rocks and rubble in tide pools and on fringing reefs. Worn shells are abundant in beach drift.

This species was described from the Hawaiian Islands and occurs throughout the Indo-West Pacific from Mauritius and Ceylon to the Ellice Islands, Fiji, and southern Japan.

Granulina vitrea (Laseron, 1957). Fig. 99 F, G. Length, 1.1 mm; diameter, 0.6 mm. *Shell:* pyriform; spire invisible; white. *Spire:* apex rounded, the spire invisible and covered by callus. *Sculpture:* microscopic growth striae only. *Aperture:* narrow; outer lip as long as the spire, thick, minutely denticulate on the inner edge; columella with two moderately strong folds. *Color:* white.

These marginellids are occasionally found in tide pools and on reefs but are more common at depths of from 8 to 50 m.

G. vitrea was described from Port Curtis, Queensland, and also occurs in the Kermadec Islands.

Volvarina fusiformis (Hinds, 1844). Fig. 99 B. Length, 3 mm; diameter, 1.5 mm. *Shell:* biconic, spire projecting, arcuate; white. *Spire:* apex blunt, domed; teleoconch

of three whorls; abapical suture only clearly defined. *Sculpture:* microscopic growth striae only. *Aperture:* narrow apically, widening abapically, two-thirds the length of the spire; outer lip denticulate, margin sinuous; columella with four folds. *Color:* white. *Animal:* mantle transparent white, mottled with dark red and flake white; papillae sparse, simple; foot slightly cleft anteriorly.

V. fusiformis is common on the undersurfaces of algal-encrusted rocks in tide pools and on fringing reefs.

This marginellid was described from Bourbon and is widely distributed in the Indo-West Pacific from Mauritius to the Torres Straits and southern Japan. The Hawaiian shells are similar to *Baroginella volunta* Laseron, 1957, from Queensland, but the apical whorls are wider than they are in the Australian shells.

Additional Records

Shells which can be ascibed to *Marginella debilis* Pease, 1871d (= *M. australis* Hinds, Redfield, 1869) and included in the synonymy of *Granula sandwicensis* may be unidentifiable from Pease's description of a shell which is "small, subpyriform, thin . . . finely striated longitudinally" from the Hawaiian Islands.

Family **Mitridae**[1]

The shells of the mitrids have been so called because of their somewhat fancied resemblance to the fusiform shape of a bishop's miter. A distinguishing feature is a series of strong columellar plaits or folds present on the rather straight columella. Mitrid shells, however, exhibit a wide range of size, shape, color, and sculpture. In size they range from less than 10 mm to more than 150 mm in length; in shape they are ovate to fusiform; in color they are among the most brilliant of tropical gastropods and among the most somber; and in sculpture some are smooth and glossy, others spirally striate, and still others are axially ribbed.

More than 500 species of Recent miters are recognized (Cernohorsky, 1970b). Most species are found in the Indo-West Pacific, lesser numbers in temperate waters. Perhaps 85 species are found in Hawaiian waters, a figure to be contrasted with the 135 species recorded from Fiji (Cernohorsky, 1965). Because of the great number of species and the variety of shell form, mitriform gastropods are difficult to place in genera and higher categories. The traditional family Mitridae has been most usefully separated into two families: the Mitridae *sensu stricto;* and the Vexillidae (Ponder, 1972a) (= Costellariidae *fide* Cernohorsky, 1976a); and a third family associated with the group, the Volutomitridae (Cernohorsky, 1970b). A synopsis of some of the conchological and anatomical features of the three families is shown in Table 2 (adapted from Ponder, 1972a).

---

[1]Mrs. Jean Cate, Mr. Walter O. Cernohorsky, Curator of Mollusks, Auckland Institute and Museum, and Mr. Norman Tebble, Director, Royal Scottish Museum, helped with the taxonomic problems of this mitrid section during the early stages of the preparation of the monograph. Mr. Richard Salisbury contributed a great deal to the section during the latter stages.

TABLE 2

FEATURE	MITRIDAE	COSTELLARIIDAE	VOLUTOMITRIDAE
Shell			
Outer lip	smooth	lirate	smooth
Predominant sculpture	smooth or spiral	axial	smooth or axial
Hypobranchial secretion	purple	yellow-green	colorless
Alimentary canal			
Proboscis	long	moderately long or short	short
Epiproboscis	present	absent	absent
Mouth	large, with a peristomal rim	small, no peristomal rim	small, no peristomal rim
Valve of Leiblein	small or absent	large	large
Gland of Leiblein	absent	moderately large or small	very small
Egg capsules	vase-shaped	inverted hemispherical	hemispherical
Operculum	absent	absent	present in some

Mitrids are both rock- and sand-dwellers. In Hawaii nine species are found in the intertidal (as well as to depths of several meters), including five of the seven species of the subgenus *Strigatella*.

All miters for which the food habits are known are carnivorous. Kohn (1970) described specimens of *Mitra (Strigatella) litterata* feeding on sipunculid worms on solution benches on Oahu; J. B. Taylor (1975) reported juveniles of *Mitra (Strigatella) assimilis* from Kaneohe Bay, Oahu, feeding on small mollusks in the laboratory. The sexes are separate, fertilization is internal, and the eggs are deposited in vase-shaped capsules attached to a hard substrate (Fig. 100). The conical protoconch of all Hawaiian miters and the life histories of those which are known suggest a pelagic veliger stage is present. Ten species of mitriform veligers were identified in the plankton of Kaneohe Bay, Oahu, by J. B. Taylor (1975); all had four lobes and all were strong swimmers.

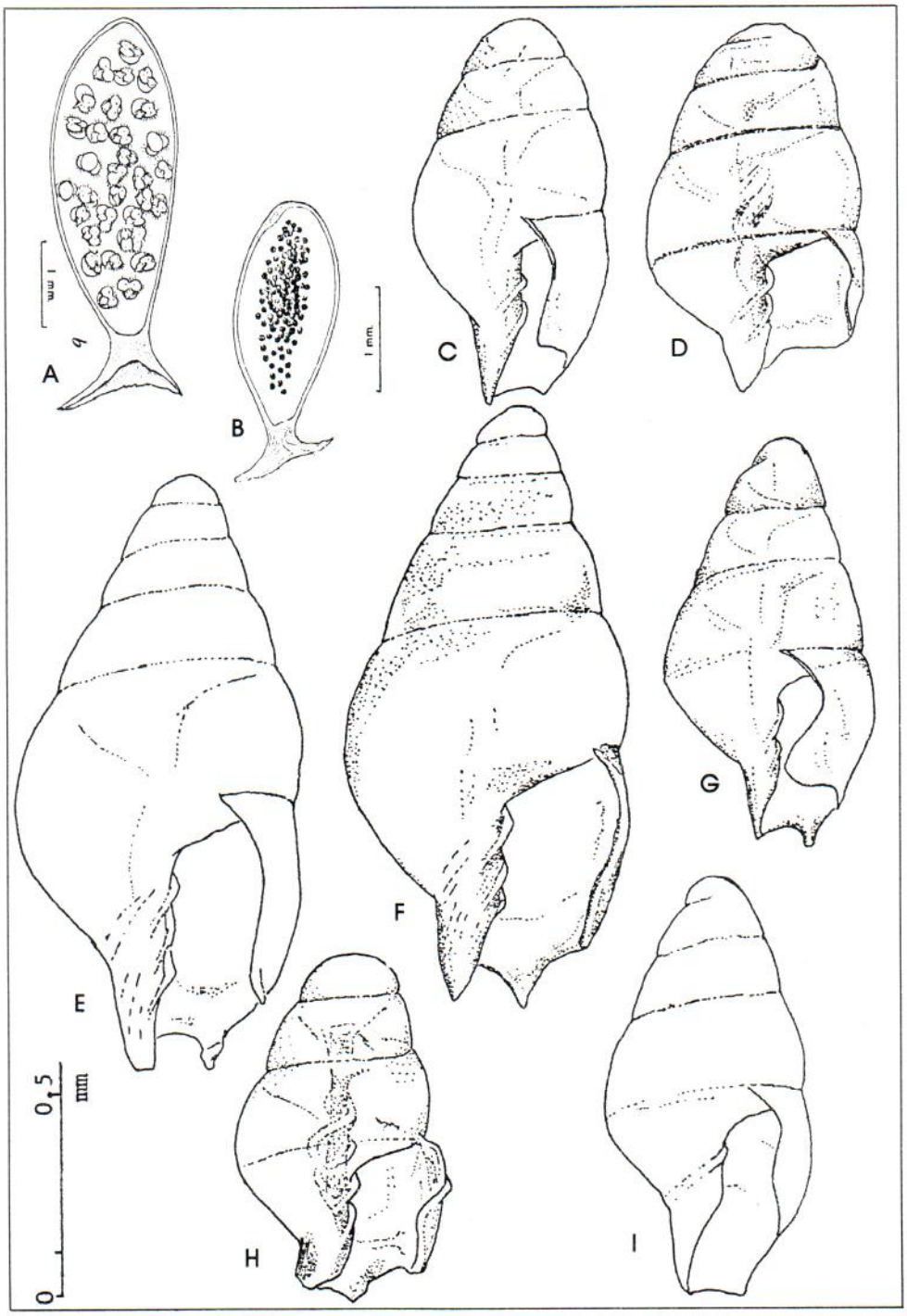


Figure 100.—**Mitridae.** A. Egg capsule with veligers, *Mitra (Strigatella) assimilis*. B. Egg capsule with embryos, *M. (S.) pellisserpentis*. C. Premetamorphic protoconch, *Mitra mitra*. D. Premetamorphic protoconch, *M. (S.) litterata*. E. Premetamorphic protoconch, *Cancilla granatina*. F. Premetamorphic protoconch, *Neocancilla waikikiensis*. G. Premetamorphic protoconch, *Imbricaria olivaeformis*. H. Premetamorphic protoconch, *Scabricola newcombii*. I. Premetamorphic protoconch, *Subcancilla interlirata*. (A and B from Ostergaard, 1950; C - I from J. B. Taylor, 1975.)

TABLE 3

FEATURE	*M. (Dibaphus)*	*M. (Mitra)*	*M. (Nebularia)*	*M. (Strigatella)*
Size	30 mm	11-97 mm	15-50 mm	7-20 mm
Shape	cylindrical	fusiform to fusiform-ovate	fusiform and biconic	obovate; broadly fusiform
Sculpture	spiral striae	smooth; spiral grooves; coronate sutures	spiral cords and striae	smooth; fine spiral striae
Outer lip	thick, crenulate	thick, crenulate	thick, crenulate	swollen
Habits	subtidal	rock, coral, sand; predominantly subtidal	rock and coral; predominantly subtidal	rock and reef; predominantly intertidal

I record 49 species of the Mitridae *sensu stricto* from Hawaii. Of these, 31 (63 percent) are species which are widespread in the Indo-West Pacific, 10 (20 percent) are restricted to the Pacific Basin, and eight (17 percent) are endemic. Five of the eight presumed endemic species or subspecies are in the subfamily Imbricariinae.

In the following descriptions all ranges apart from the Hawaiian records are from Cernohorsky (1965; 1970b; 1976a).

Subfamily **Mitrinae**

The shells of the Mitrinae are smooth, with fine punctate spiral striae, irregular axial ribs, or with spiral cords. These miters are predominantly associated with hard substrates, although both *Mitra mitra* and *M. papalis* are well-known sand-dwellers. The subfamily includes some of the most commonly found shallow water miters in the Hawaiian Islands. The distinguishing features of the shells and the habits of the four subgenera of *Mitra* found in Hawaii are shown in Table 3.

Mitra (Mitra) coffea Schubert and Wagner, 1829. Fig. 102 H. (Synonyms: *M. thaanumiana* Pilsbry, 1921; *M. ambigua* Swainson, Edmondson, 1933.) Length, 41 mm; diameter, 15 mm; aperture length, 24 mm. *Shell:* fusiform, solid; with punctate spiral striae; brown. *Spire:* projecting; base and spire straight; periphery of last whorl convex; suture oblique and channeled. *Sculpture:* fine, evenly spaced punctate spirals; smooth interstices. *Aperture:* wide, flaring basally; more than half the length of the

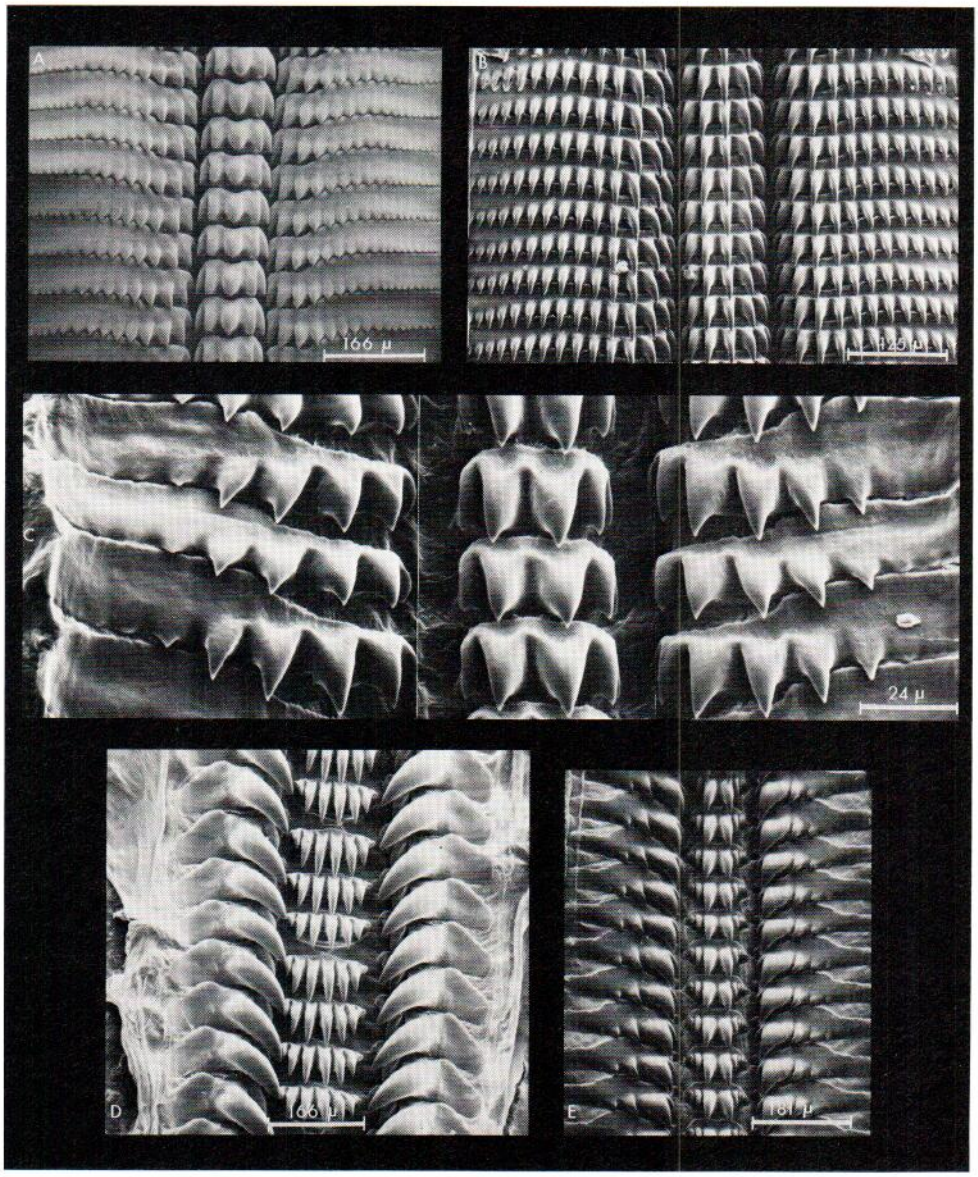


Figure 101.—Mitrid radulae. A. *Mitra mitra*. B. *M. (Nebularia) fuscescens*. C. *M. (Strigatella) pellisserpentis astricta*. D. *Swainsonia newcombi*. E. *Imbricaria punctata*.

spire; outer lip with distant, elongate denticles; columella with five or six folds. *Color:* live-collected specimens brown, occasionally with small white dots scattered over the last whorl, interior of aperture deep brown, denticles white; beachworn shells yellow-brown to buff.

M. coffea is an uncommon shallow-water species, found occasionally under rocks on reefs and to depths of 6 m. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

This species is widely distributed in the Indo-West Pacific, from Madagascar to the Ryukyu Islands, Marshall Islands, and Polynesia.

Mitra (Mitra) incompta (Solander in Lightfoot, 1786). Fig. 102 F. Length, 66 mm; diameter, 17 mm; aperture length, 29 mm. *Shell:* fusiform-elongate; solid; flat-sided; with prominent axial and spiral ridges; cream axially streaked with brown. *Spire:* whorls flat-sided; suture distinct. *Sculpture:* prominent axial and spiral ridges giving the shell a decussate surface. *Aperture:* wide; shorter than spire; outer lip thick, crenulate; columella with four to six folds. *Color:* cream with axial brown streaks, aperture yellow; periostracum opaque, dark brown.

This miter is uncommon, occurring at depths from 16 to 148 m.

M. incompta ranges from East Africa to the Philippines. It is rarely collected in the Central Pacific.

Mitra (Mitra) maui Kay, new species. Figs. 102 I, J. Length, 30 mm; diameter, 10 mm; aperture length, 17 mm (holotype). Length range in five shells, 14 to 30 mm. *Shell:* fusiform-ovate; with flat spiral cords; cream axially blotched with red-brown. *Spire:* protoconch of three and one-quarter glossy, conical whorls; teleoconch of seven slightly convex whorls; suture prominent, impressed, shoulder barely angulate. *Sculpture:* flat spiral cords, about twenty on the last whorl, seven on the penultimate whorl; width of interspaces between spiral cords variable, the four apical grooves on the last whorl about equal in diameter to the cords, the abapical grooves very narrow; interspaces with fine axial threads, the threads prominent in the wider grooves, appearing almost punctate in the narrow interspaces. *Aperture:* moderately wide; longer than spire; outer lip thin, barely crenulate; columella with four oblique folds, the abapical fold nearly obsolete in all shells examined; siphonal canal recurved; siphonal notch distinct. *Color:* cream with axially oriented angular blotches of red-brown running from suture to base on the last whorl and restricted to just below the suture on the other whorls; in worn shells the axial blotches may be broken into discrete blocks.

These miters are uncommon, dredged at depths of 200 m.

Type locality: off Kewalo, Oahu, from a depth of 200 m. *Holotype:* B. P. Bishop Museum No. 9828. *Paratypes* (five): B. P. Bishop Museum.

These shells are reminiscent of those of *M. nubila hawaiiensis* in shape but in sculpture are more nearly like those of *M. (Nebularia) rubiginosa* Reeve, 1844 from the western Pacific (figured by Cernohorsky, 1976a). The variable development of the width of the spiral grooves is like that figured for shells of the Miocene fossil *(M. (M.) junghuhni* K. Martin, 1880 (in Cernohorsky, 1976a)). Derivation of name: *maui,* Hawaiian demigod famous for his tricks. Named because of the tantalizing occurrence of fragments of this miter.

Mitra (Mitra) mitra (Linnaeus, 1758). Figs. 100 C; 102 A. (Synonym: *Mitra episcopalis* Linnaeus, Garrett, 1880.) Length, 74 mm; diameter, 29 mm; aperture length, 31 mm. *Shell:* fusiform-elongate, solid; smooth; white with spirals of large, angular red spots. *Spire:* projecting; suture impressed. *Sculpture:* occasional fine punctate spiral striae on an otherwise smooth shell. *Aperture:* equal to or less than the length of the spire; outer lip thick, with spiny crenulations on abapical half; columella

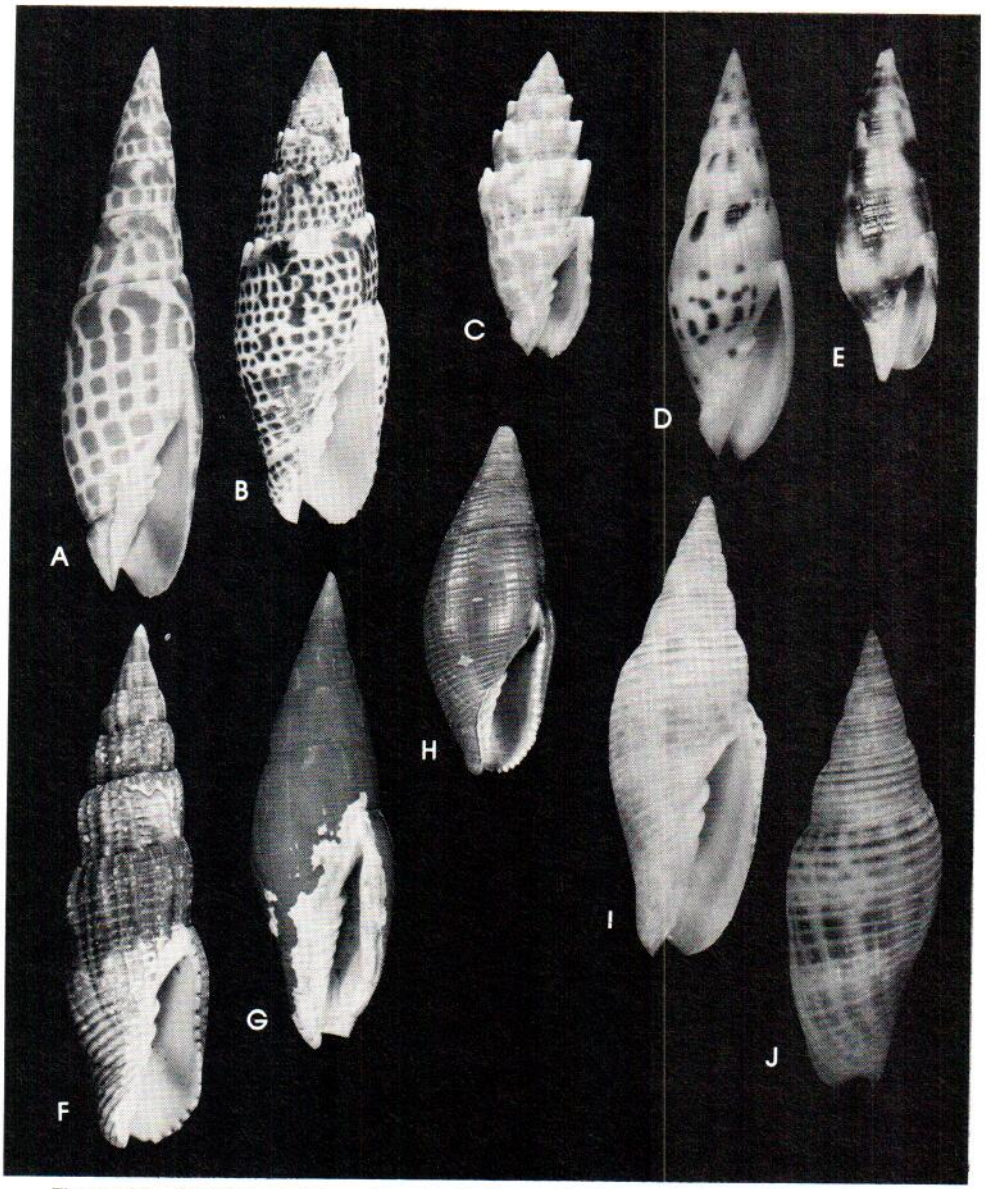


Figure 102.—**Mitridae.** A. *Mitra mitra*, length 74 mm. B. *M. papalis*, length 97 mm. C. *M. stictica*, length 45 mm. D. *M. nubila hawaiiensis*, length 52 mm. E. *M. ustulata*, length 41 mm. F. *M. incompta*, length 65 mm. G. *M. pele*, length 40 mm. H. *M. coffea*, length 40 mm. I, J. *M. maui*, length 30 mm (holotype).

with four or five folds. *Color:* white with irregular orange or red-orange blotches usually arranged in spiral rows; aperture creamy yellow.

M. mitra is common at depths of from 13 to 130 m in sand, with most shells found between 20 and 30 m. Veligers are found in the plankton in March; they metamorphose when slightly more than three whorls are complete, at a length of 1000 μm (J. B. Taylor, 1975).

This miter is found throughout the Indo-West Pacific, from East Africa to southern Japan, the Marshall Islands, and Polynesia. In many Pacific localities *M. mitra* is found in shallow water by its tracks on exposed sand bars and in lagoons.

Mitra (Mitra) nubila hawaiiensis Kay, new subspecies. Fig. 102 D. (Synonyms: *Mitra lamarckii* Deshayes, Mant, 1923; *M. nebulosa* Swainson, Weaver, 1964c; *M. nubila lamarckii* Deshayes, 1832, Cernohorsky, 1976a.) Length, 46 mm; diameter, 16 mm; aperture length, 23 mm (holotype). Length range of 23 shells, 20 to 56 mm. *Shell:* fusiform-ovate; solid; smooth; cream splashed with brown. *Spire:* attenuate, teleoconch of about six slightly inflated whorls; suture impressed. *Sculpture:* with fine spiral striae on an otherwise smooth surface. *Aperture:* moderately wide; about equal in length to the spire; outer lip finely crenulate; columella with four or five folds. *Color:* cream with a single spiral of rectangular brown spots at the suture on the last whorl and four spirals of smaller spots abapically; apical whorls with a single spiral of brown spots below the suture; aperture white.

These miters are rare. Of the 23 shells for which I have records, two were collected alive at depths of 16 to 20 m (Weaver, 1964c; Corn, 1973), one was dredged from a depth of 60 m (B. P. Bishop Museum collection), one was recorded from Niihau, presumably from beach drift (Cernohorsky, 1976a), and 19 come from dredge spoils from Honolulu Harbor, Oahu.

Type locality: Honolulu Harbor, Oahu, from dredge spoils. *Holotype:* B. P. Bishop Museum No. 195739. *Paratypes* (12): B. P. Bishop Museum.

Mitra lamarckii Deshayes, 1832, was described from a shell 70 mm in length but without figure or type locality. The type is not in the École des Mines in Paris (Cernohorsky, 1976a). Reeve (1844) and Sowerby (1874) purportedly illustrated the species; neither provided locality data. Cernohorsky (1976a) declared Kewalo Harbor, Honolulu, Oahu, as the type locality, stating, "The species was first reported by C. Mant (1923) from dredgings at Kewalo Harbor, Honolulu, Oahu and this correct locality indication is designated as the type locality of *M. nubila lamarckii*."

Application is now being made to the International Commission on Zoological Nomenclature to have *M. lamarckii* declared a *nomen dubium* for the following reasons: (1) it is extremely unlikely that Deshayes could have had this rare Hawaiian miter in his possession in 1832; (2) the dimensions cited by Deshayes are inconsistent with those of recent Hawaiian shells; and (3) the description is sufficiently general that it could apply to any one of several cream-colored miters with brown spots. The shells illustrated by Reeve (1844) and Sowerby (1874) also appear to represent a miter different from the Hawaiian miter.

Prior to 1832, when Deshayes described *M. larmarckii,* there had been only four voyages to Hawaii from which mollusks are recorded (see Historical Resumé). All of the shells mentioned as from those voyages are found in the intertidal or in shallow water, or they are common in beach drift. The mitrid shells in question, however, with one exception, have been found either in dredge spoils or at depths of more than 16 m. There are no records of dredging in Honolulu Harbor prior to 1832 which might have served as a source for the specimen.

The discrepancy in length between the shell described by Deshayes and the recorded length of recently collected Hawaiian shells is too great to be dismissed. The

longest recorded Hawaiian shell representing this species is 56 mm (B. P. Bishop Museum collection) and mean length of 23 shells is 36.4 mm. Nor do the shells illustrated by Reeve (1844) and Sowerby (1874) appear to represent these Hawaiian miters. The length/width ratio of the Reeve shell is 2:3, that of the Sowerby shell is 2:6. The mean length/width ratio of the Hawaiian shells is 2:8. Neither the Reeve nor the Sowerby shell is now in the British Museum (Natural History) to confirm this hypothesis, although there are two specimens of the Hawaiian miter in the London collections, both from Honolulu Harbor dredge spoils.

These Hawaiian miters are recognized as an endemic subspecies of *M. nubila* (Gmelin, 1791). *M. nubila nubila* ranges from the Red Sea to Tonga and the Phoenix Islands (Cernohorsky, 1976a). The Hawaiian shells are distinguished by their weaker spiral sculpture and the rectangular brown spots which constitute the color pattern (Cernohorsky, 1976a).

Mitra (Mitra) papalis (Linnaeus, 1758). Fig. 102 B. Length, 97 mm; diameter, 37 mm; aperture length, 48 mm. *Shell:* fusiform, solid; suture coronate; white with spirals of red spots. *Spire:* projecting, of six convex whorls plus the protoconch; suture coronate. *Sculpture:* fine punctate spiral grooves. *Aperture:* straight; about equal in length to spire; outer lip thick, crenulate; columella with five or six folds. *Color:* white, with spirals of bold red-brown blotches; aperture creamy yellow.

These miters are fairly common at depths of from 6 to 50 m in sand or silt. When disturbed the animals secrete a purple dye (Cross, 1967d).

M. papalis occurs from East Africa to southern Japan, the Ryukyu Islands, Polynesia, and Clipperton Island.

Mitra (Mitra) pele Cernohorsky, 1970a. Fig. 102 G. Length, 40 mm; diameter, 14 mm; aperture length, 23 mm. *Shell:* fusiform; smooth; dark brown, aperture with a prominent white callus. *Spire:* tapering; teleoconch of four and a half almost flat-sided whorls; suture distinct but not deep. *Sculpture:* smooth with microscopic spiral grooves. *Aperture:* about equal in length to the spire, moderately narrow; labial lip thick, simple; columella with seven oblique folds; siphonal canal straight. *Color:* tan under a dark brown periostracum; callus white.

Mitra pele was described from a specimen dredged from about 140 m off Pitcairn Island. Specimens have been dredged off leeward Oahu at depths of 100 m.

Mitra (Mitra) stictica (Link, 1807). Figs. 82 D; 102 C. (Synonym: *Mitra pontificalis* Lamarck, Garrett, 1880.) Length, 45 mm; diameter, 17 mm; aperture length 22 mm. *Shell:* fusiform-ovate, solid; suture sharply coronate; with punctate spiral striae; white blotched with orange-red. *Spire:* turreted, whorls flat-sided and angulate at the suture; suture channeled and coronate. *Sculpture:* punctate spiral striae on a smooth shell. *Aperture:* wide, flaring; about equal in length to the spire; outer lip thick, dentate; columella with four or five folds. *Color:* white with bold orange-red blotches arranged irregularly. The shells are often encrusted with algae and other calcareous deposits.

These miters are occasionally found on fringing reefs and in tide pools, and are common at depths of 20 to 40 m in sandy pockets of subtidal coral communities.

M. stictica is widely distributed throughout the Indo-West Pacific, from East Africa to southern Japan, the Ryukyu Islands, Micronesia, and Polynesia.

Mitra (Mitra) ustulata Reeve, 1844. Fig. 102 E. (Synonym: *Mitra kamehameha* Pilsbry, 1921.) Length, 41 mm; diameter, 15 mm; aperture length, 24 mm. *Shell:* fusiform, solid; with fine spiral and axial striae; white to cream, blotched with brown. *Spire:* nine to eleven moderately convex whorls; suture impressed. *Sculpture:* fine spiral striae with axial striae in the interspaces. *Aperture:* slightly shorter than spire; outer lip thick; columella with five to seven folds. *Color:* white to cream, ornamented with dark brown blotches usually arranged in spiral rows but tending to coalesce in axial streaks.

M. ustulata is rare in Hawaiian waters, known only from a few shells collected at depths of from 5 to 22 m.

This miter is widely distributed in the Indo-West Pacific, from the Red Sea to Polynesia.

Mitra (Nebularia) aurora aurora Dohrn, 1861. Fig. 103 A. (Synonyms: *Mitra coronata aurora* Dohrn, Pilsbry, 1921; *Mitra coronata* Lamarck, Tinker, 1952.) Length, 27 mm; diameter, 11 mm; aperture length, 15 mm. *Shell:* fusiform, solid; with punctate spiral grooves; red-brown splashed with white. *Spire:* projecting, attenuate; suture channeled and coronate. *Sculpture:* punctate spiral striae or spiral ridges. *Aperture:* moderately narrow; about equal in length to the spire; outer lip finely crenulate; columella with five or six folds. *Color:* orange- to red-brown, with a narrow or wide, continuous or uneven white subsutural zone and irregular white blotches and spots distributed evenly over the last whorl; aperture and columellar plaits white.

This species is uncommon, occurring at depths of from 13 to 80 m.

Cernohorsky (1976a) distinguishes two subspecies, *M. aurora aurora* described from the Hawaiian Islands, which also occurs in the Cook, Society, and Tuamotu islands, and *M. aurora floridula* Sowerby, 1874, the shells of which have coarser sculpture and which occurs from the Red Sea to Japan and the Gilbert and Tonga islands. *M. aurora* is apparently closely related to *M. coronata*, and some shells elsewhere in their range can be arbitrarily assigned to either species. In the Hawaiian Islands *M. aurora* and *M. coronata* are consistently distinct, the shells of the former distinguished by their larger size (mean length 27 mm versus 17 mm for *M. coronata*) and blotched pattern of white splashes on a red-brown background.

Mitra (Nebularia) avenacea Reeve, 1845. Fig. 103 M. Length, 20 mm; diameter, 8 mm. *Shell:* biconic, slender; with narrow spiral cords; orange-brown. *Spire:* teleoconch of six to eight slightly inflated whorls; suture barely discernible. *Sculpture:* apical whorls slightly beaded; abapical whorls with narrow, angulate spiral cords, three on the penultimate whorl, 15-20 on the last whorl; interstices of spirals which are finely axially striate. *Aperture:* narrow, equal in height to the spire; outer lip slightly thickened, crenulate at the margin; columella with three or four folds. *Color:* orange-brown, spiral cords paler with white spots, aperture flesh.

These miters are rare, found at depths of more than 20 m.

M. avenacea occurs from Madagascar to Ceylon, the Philippines, Marshall Islands, and Samoa.

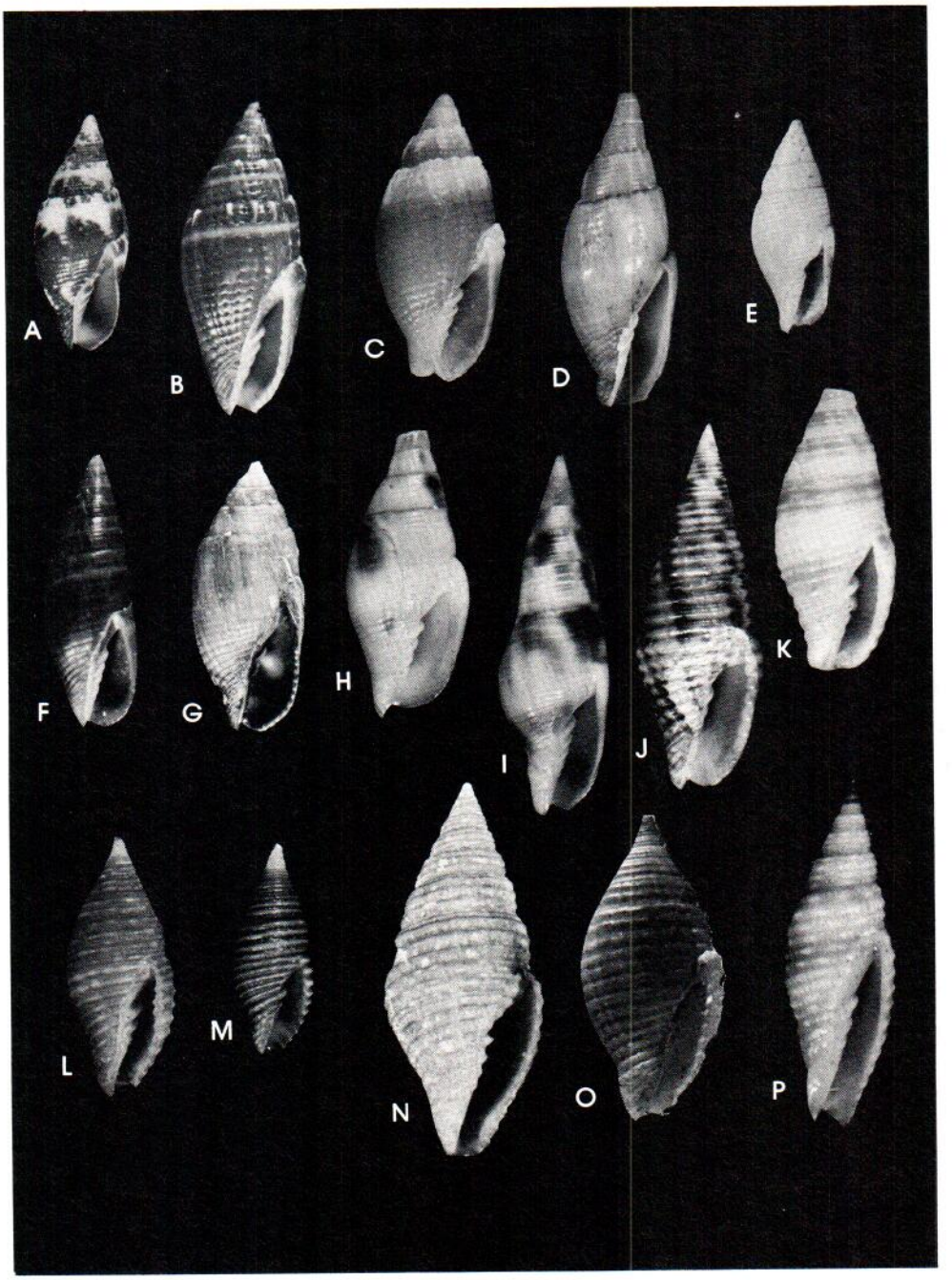


Figure 103.—*Mitra (Nebularia)*. A. *M. (N.) aurora aurora*, length 27 mm. B. *M. (N.) coronata*, length 17 mm. C. *M. (N.) lugubris*, length 19 mm. D. *M. (N.) fulvescens*, length 40 mm. E. *M. (N.) testacea*, length 20 mm. F. *M. (N.) luctuosa*, length 10 mm. G. *M. (N.) ticaonica*, length 20 mm. H. *M. (N.) coarctata*, length 23 mm. I. *M. (N.) contracta*, length 50 mm. J. *M. (N.) ferruginea*, length 37 mm. K. *M. (N.) rubritincta*, length 20 mm. L. *M. (N.) cucumerina* length 15 mm. M. *M. (N.) avenacea*, length 20 mm. N. *M. (N.) fraga*, length 40 mm. O. *M. (N.) turgida*, length 15 mm. P. *M. (N.) earlei*, length 13 mm.

Mitra (Nebularia) coarctata Reeve, 1844. Fig. 103 H. Length, 23 mm; diameter, 10 mm; aperture length, 14.5 mm. *Shell:* fusiform-ovate; solid; smooth; cream splashed with brown. *Spire:* teleoconch of about five slightly convex whorls; suture distinct, ledged. *Sculpture:* fine, shallow, microscopic spiral striae and occasional axial hairlines. *Aperture:* wide; longer than spire; outer lip thick, concave medially; columella with five oblique folds. *Color:* cream splashed with large dark brown blotches.

Shells are rare, found at depths of about 20 m.

M. coarctata was described from the Tuamotus and is recorded from the Philippines, New Guinea, Guam, and the Solomon and Cook Islands.

Mitra (Nebularia) contracta Swainson, 1820. Fig. 103 I. (Synonym: *Mitra ustulata* J. Cate, 1962b.) Length, 50 mm; diameter, 16 mm; aperture length, 24 mm. *Shell:* fusiform, solid; with fine spiral striae; cream with red-brown blotches. *Spire:* teleoconch of nine to eleven moderately convex whorls; suture impressed. *Sculpture:* fine spiral striae with axial striae in the interspaces. *Aperture:* moderately wide; equal in height to the spire; outer lip thick, smooth; columella with six folds. *Color:* white to cream, ornamented with dark brown blotches generally arranged in spiral rows but tending to coalesce into axial streaks; aperture yellow.

These shells are rare in Hawaii, known only from a few shells collected at depths of from 5 to 20 m.

M. contracta is widely distributed in the Indo-West Pacific, ranging from East Africa to the Philippines and the Tuamotu Islands.

Mitra (Nebularia) coronata Lamarck, 1811. Fig. 103 B. (Synonyms: *Mitra lugubris honoluluensis* Pilsbry, 1921; *M. tiarella* A. Adams, J. Cate, 1962a; *M. crassula* Dall MS, J. Cate, 1963.) Length, 17 mm; diameter, 6 mm; aperture length, 9 mm. *Shell:* fusiform-ovate, solid; with punctate spiral striae; brown, sutural crenulations tipped with white. *Spire:* attenuate, sharp, of six or seven whorls; suture channeled and crenulate. *Sculpture:* with punctate spiral striae separating equally spaced, flat spiral cords; axial sculpture of obsolete striae. *Aperture:* moderately narrow; about half the length of the spire; outer lip crenulate; columella with five or six folds. *Color:* brown, sutural crenulations tipped with white and with a narrow, white sutural band; columella and aperture white. Beachworn shells orange-brown.

These miters are moderately common in shallow water and to depths of 100 m.

M. coronata is widely distributed in the Indo-West Pacific, from East Africa to southern Japan and the Ryukyu Islands and Polynesia.

These shells are easily distinguished from those of *M. aurora* by their smaller size (mean length of *M. aurora* is 27 mm), brown background and white sutural crenulations.

Mitra (Nebularia) cucumerina Lamarck, 1811. Fig. 103 L. (Synonym: *Mitra peregra* Reeve, Garrett, 1880.) Length, 15 mm; diameter, 7 mm; aperture length, 9 mm. *Shell:* biconic, attenuate at both ends; with elevated spiral cords; red-brown maculated with white. *Spire:* protoconch conical, of three smooth, white whorls; teleoconch attenuate at base; suture deep. *Sculpture:* elevated spiral cords with axial striae in the interspaces. *Aperture:* narrow, tapering; shorter than spire; outer lip

denticulate; columella with three or four folds. *Color:* red-brown or brown with small white maculations on the spiral cords; beachworn shells orange-brown.

This is a common shallow-water species in tide pools and on reefs, and has been recorded to depths of 100 m. Veliger larvae are found in the plankton from March through September; they metamorphose when three and one-quarter whorls are complete, at a length of 1000 μm (J. B. Taylor, 1975).

M. cucumerina is widely distributed in the Indo-West Pacific, ranging from East Africa to the Philippines, Micronesia, and Polynesia.

Mitra (Nebularia) earlei Cernohorsky, 1977b. Fig. 103 P. Length, 13 mm; diameter, 5 mm; aperture length, 7 mm. *Shell:* fusiform-elongate; with spiral cords crossed by axial ribs; white with three spiral bands of brown. *Spire:* protoconch of three and one-half smooth, conical whorls; teleoconch of four whorls, the last the largest; suture indistinct. *Sculpture:* strong, elevated spiral cords crossed by axial ribs which produce a clathrate effect especially on the last whorl. *Aperture:* narrow; slightly longer than spire; outer lip convex, crenulated by the spiral cords; columella with four or five oblique folds. *Color:* white tinted with lavender in live-collected specimens, with three spirals of orange-brown on the last whorl and some white spots on the spiral cords; protoconch brown; apical whorls violet.

These miters are common at depths of 100 to 200 m.

M. earlei was described from the Hawaiian Islands. Cernohorsky (1977) notes that although the sculpture is typical of that of *Cancilla (Domiporta)* the radula is that of a typical mitrid.

Mitra (Nebularia) ferruginea Lamarck, 1811. Fig. 103 J. Length, 37 mm; diameter, 15 mm; aperture length, 18 mm. *Shell:* fusiform, solid; with prominent spiral keels; white blotched with red-brown. *Spire:* teleoconch of 9 to 10 slightly convex whorls; suture moderately impressed. *Sculpture:* prominent, elevated spiral cords (16 to 21 on the last whorl), usually flattened or slightly rounded at the summits; interspaces moderately V-shaped and with fine axial threads which may be obsolete on the last two whorls. *Aperture:* equal in length to the spire; outer lip thick and prominently denticulate; columella with five oblique folds. *Color:* white or cream, with rusty brown blotches and streaks; interior of aperture golden brown.

This mitrid is common at depths of from 10 to 100 m.

M. ferruginea occurs throughout the Indo-West Pacific from the Red Sea to the Ryukyu Islands, southern Japan, Micronesia, Polynesia, and Clipperton Island.

Mitra (Nebularia) fraga Quoy and Gaimard, 1833. Fig. 103 N. (Synonym: *Mitra tornata* Reeve, Cross, 1973.) Length, 40 mm; diameter, 15 mm; aperture length, 20 mm. *Shell:* biconic, attenuate at both ends; with elevated spiral cords; red-brown with orange spots on the spiral cords. *Spire:* protoconch of two smooth white whorls; teleoconch attenuate at the base; suture weakly impressed. *Sculpture:* elevated, rounded spiral cords; interspaces V-shaped and with axial threads which may override the spiral cords. *Aperture:* equal in height to the spire; narrow; outer lip thick and crenulated; columella with four or five oblique folds. *Color:* dark red to red-brown with small close-set orange spots on the spiral cords.

These miters are uncommon, dredged at depths of 60 to 100 m.

M. fraga was described from the Philippine Islands and occurs throughout the Indo-West Pacific from the Red Sea to the Philippines, southern Japan and the Ryukyu Islands, Micronesia, and Polynesia. Elsewhere in its range it is found at depths of 0 to 30 m (Cernohorsky, 1976a).

Mitra (Nebularia) fulvescens Broderip, 1836. Fig. 103 D. (Synonyms: *Mitra ostergaardi* Pilsbry, 1921; *M. pararhodia* Dall MS, J. Cate, 1963; *M. golischi* Dall MS, J. Cate, 1963.) Length, 43 mm; diameter, 15 mm; aperture length, 22 mm. *Shell:* fusiform, solid; outer lip slightly concave; red-brown to dark brown, aperture flesh. *Spire:* conic, somewhat flattened at the periphery, last whorl concave toward base; suture finely crenulate. *Sculpture:* widely spaced punctate spiral striae on a smooth shell and spiral cords toward base. *Aperture:* constricted apically but effuse at base; about equal in length to spire; outer lip bluntly denticulate; columella with four or five folds. *Color:* dark chocolate brown, aperture flesh; worn shells orange or yellow.

M. fulvescens is uncommon, recorded from depths of about 50 m.

This miter is distributed throughout the Indo-West Pacific, occurring in Mauritius, the Philippines, Palau, the New Hebrides, the Society Islands, and the Line Islands. The Hawaiian shells are longer and proportionately broader than those occurring elsewhere in the Pacific: mean length of Hawaiian shells is 31.4 mm and the length/breadth ratio is 2.7; elsewhere in the Pacific mean length is 25.7 mm and the length/breadth ratio is 3.3.

Mitra (Nebularia) luctuosa A. Adams, 1853a. Fig. 103 F. (Synonyms: *Mitra alcida* Dall MS, J. Cate, 1963; *M. diamantina* Dall MS, J. Cate, 1963.) Length, 11 mm; diameter, 4 mm; aperture length, 5 mm. *Shell:* fusiform-ovate, slender; with punctate spiral striae; dark brown. *Spire:* projecting; five or six rather flat whorls exclusive of the protoconch; suture impressed. *Sculpture:* fine, punctate spiral striae which become cordlike on the base. *Aperture:* narrow; about equal in length to the spire; outer lip smooth with a few obsolete denticles basally; columella with three or four folds. *Color:* dark brown, occasionally with a faint subsutural band.

M. luctuosa is not uncommonly collected under coral heads at depths of 3 m to 10 m, and has been dredged as deep as 100 m.

This species is widely distributed in the Indo-West Pacific, from East Africa to the Philippines, New Caledonia, Fiji, the Society Islands, and the Line Islands.

Mitra (Nebularia) lugubris Swainson, 1821. Fig. 103 C. (Synonym: *Mitra coronata* Lamarck, J. Cate, 1962a.) Length, 19 mm; diameter, 8 mm; aperture length, 12 mm. *Shell:* fusiform-ovate, solid; with spiral cords and punctate spiral striae; dark brown with a broad white sutural band. *Spire:* projecting, attenuate; whorls convex; suture channeled, coarsely crenulate. *Sculpture:* prominent spiral cords and axial striae. *Aperture:* moderately narrow; longer than spire; outer lip thick and crenulate; columella with four or five folds. *Color:* dark brown with a broad white band at the suture; aperture blue-white; beachworn shells red-brown.

This species is uncommon, found at depths from 3 to 100 m.

M. lugubris is found in the Pacific Basin from southern Japan and the Philippines to southeastern Australia and through Polynesia.

Mitra (Nebularia) rubritincta Reeve, 1844. Fig. 103 K. Length, 20 mm; diameter, 7 mm; aperture length, 10 mm. *Shell:* ovate or elongate-ovate; solid; with prominent spiral cords; white spirally banded with red. *Spire:* teleoconch of about eight flat-sided whorls; suture weakly impressed, ledged. *Sculpture:* three to five prominent spiral cords on each whorl, the interspaces concave and axially striate; broad, rather coarse axial ribs appearing on the abapical part of the penultimate whorl and persisting on the last whorl. *Aperture:* wide; equal in height to the spire; outer lip thick, with short denticles at the margin; columella with five folds. *Color:* white, with wide spiral bands of dark red, sometimes with two rows of spiral blotches on the last whorl.

These miters are rare in Hawaii, found at depths of about 16 m.

M. rubritincta was described from the Philippine Islands and ranges from Mauritius to the Philippines, Micronesia, and Polynesia.

Mitra (Nebularia) testacea Broderip, 1836. Fig. 103 E. (Synonym: *Mitra antoni* Dohrn, 1860.) Length, 20 mm; diameter, 8 mm; aperture length, 10 mm. *Shell:* elongate-ovate; solid; with shallow spiral grooves; yellow brown. *Spire:* projecting; teleoconch of six or seven flat-sided whorls; suture distinct, ledged. *Sculpture:* narrow, sharply incised spiral grooves which may be punctate or striate, the grooves tending to become obsolete in the center of the last whorl. *Aperture:* narrow; equal in height or shorter than the spire; outer lip thick, constricted near the center; columella with four oblique folds. *Color:* dark yellow-brown or orange-brown; aperture and columella lighter brown.

Shells are rare, found in beach drift.

M. testacea is restricted in its distribution to Polynesia (the Gilbert, Society, Tuamotu, Gambier, and Pitcairn islands) apart from its occurrence in Hawaii (Cernohorsky, 1976a).

Mitra (Nebularia) ticaonica Reeve, 1844. Fig. 103 G. (Synonyms: *M. subrostrata* Sowerby, 1874; *Mitra ticaonica vagans* Pilsbry, 1921; *M. pupiformis* Dall MS, J. Cate, 1963.) Length, 21 mm; diameter, 9 mm; aperture length, 14 mm. *Shell:* obovate, solid; with impressed spiral striae; dark brown. *Spire:* last whorl obese; suture impressed. *Sculpture:* fine spiral striae which become prominent cords basally. *Aperture:* narrow; longer than spire; outer lip finely crenulate; columella with four or five folds. *Color:* dark chocolate-brown, rarely chestnut with darker axial streaks; columella folds white.

These miters are common, found intertidally under rocks on fringing reefs, on solution benches, and to depths of 10 m. Kosuge (1969) records post-Pleistocene fossils from Mokapu Peninsula, Oahu (as *M. crassa).*

M. ticaonica occurs throughout the Indo-West Pacific from East Africa to the Philippines and Polynesia (Gilbert, Tonga, and Society islands).

Mitra (Nebularia) turgida Reeve, 1845. Fig. 103 O. (Synonym: *Mitra ericea* Pease, 1860a.) Length, 15 mm; diameter, 7 mm; aperture length, 8 mm. *Shell:* fusiform-ovate, attenuate at both ends; with coarse spiral cords; light brown. *Spire:* attenuate, concave, small in proportion to last whorl which is inflated; suture deep.

Sculpture: coarse spiral cords with interspaces of equal diameter which are finely axially striate. *Aperture:* narrow; about equal in length to the spire; outer lip finely crenulate; base excavate; columella with three or four folds. *Color:* light brown to chestnut; apex white.

This species is known only from beachworn shells collected in drift.

M. turgida occurs throughout the Indo-West Pacific, from East Africa to the Philippines, Micronesia, and Polynesia.

Mitra (Strigatella) acuminata Swainson, 1824. Fig. 104 I. Length, 30 mm; diameter, 11 mm; aperture length, 16.5 mm. *Shell:* broadly fusiform, apex acuminate; solid; smooth; yellow-brown, aperture white. *Spire:* teleoconch of six whorls; suture distinct, incised. *Sculpture:* microscopic spiral striae which are more prominent on the apical whorls than on the last whorl. *Aperture:* narrowly ovate; longer than spire; outer lip smooth, thickened internally; columella with four oblique folds. *Color:* yellow-brown; aperture white.

These miters are rare in Hawaii, recorded from Honolulu Harbor dredgings and live-collected only on the Kona Coast of Hawaii. Fossils are recorded from Mokapu Peninsula, Oahu (Kosuge, 1969).

M. acuminata is widespread throughout the Indo-West Pacific, from East Africa through the Philippines and Japan to Polynesia and Micronesia.

Mitra (Strigatella) assimilis Pease, 1868a. Figs. 100 A; 104 H. (Synonym: *Mitra auriculoides* Reeve, Garrett, 1880.) Length, 17 mm; diameter, 8 mm; aperture length, 11 mm. *Shell:* obovate, solid; with punctate spiral striae; red- to chocolate-brown spirally banded with white. *Spire:* protoconch conical, red-brown; teleoconch with last whorl obese; suture channeled. *Sculpture:* fine punctate spiral striae usually obsolete in the center of the last whorl but forming spiral cords at the base. *Aperture:* moderately wide; longer than spire; outer lip finely crenulate and slightly flaring; columella with four or five folds. *Color:* red- or chocolate-brown, encircled with a creamy-white or yellow spiral band below the suture; the spiral band on the last whorl with small, irregular white spots; aperture blue-white. *Animal:* exposed parts red-brown, foot, siphon, and tentacles margined with white; sole of foot white; proboscis as long as the shell.

These miters are common in shallow water, found buried in sand in tide pools, shoreward on fringing reefs, and in the algal mat of solution benches. The egg capsules are vase-shaped, about 4 mm in length and contain about 200 ova (Ostergaard, 1950, as *M. auriculoides*). Four-lobed veliger larvae are found in the plankton from March through May and in August and October; they metamorphose when three and three-fourths to four whorls are complete, at a length of 1040 μm (J. B. Taylor, 1975). In the laboratory juveniles feed on small mollusks such as *Styliferina* and *Rissoella* (J. B. Taylor, 1975).

This species is widely distributed in the Indo-West Pacific, ranging from East Africa to the Philippines, Ryukyu Islands, and Polynesia. Cernohorsky (1976a) distinguishes the shells from those of *M. auriculoides* Reeve, 1845, which has a similar distribution, by the denticulate outer lip, longer last whorl, and more slender form.

Mitra (Strigatella) fastigium (Reeve, 1845). Fig. 104 J. (Synonyms: *Mitra fuscescens* Pease, 1860; *Strigatella brunnea* Pease, Garrett, 1880.) Length, 28 mm; diameter, 18 mm; aperture length, 15 mm. *Shell:* obovate; solid; with fine spiral grooves; dark brown. *Spire:* protoconch of three conical, yellow-white whorls; apical whorls projecting but blunt, last whorl obese; suture impressed, either minutely crenulate or smooth. *Sculpture:* fine spiral grooves on a smooth shell, the striae sometimes obsolete on central portion of last whorl and becoming spiral ridges basally. *Aperture:* outer lip thick, with a blunt denticle and flaring basally; shorter than spire; columella with four or five folds. *Color:* tan to dark brown, occasionally with a narrow light colored presutural band on the last whorl.

Shells are rather uncommon, found under rocks shoreward of fringing reefs and occasionally in tide pools.

This species is widely distributed in the Indo-West Pacific, from East Africa to southern Japan, Micronesia, and Polynesia.

Mitra (Strigatella) litterata (Lamarck, 1811). Figs. 100 D; 104 G. (Synonym: *?Mitra maculosa* Reeve, Garrett, 1880.) Length, 19 mm; diameter, 10 mm; aperture length, 12 mm. *Shell:* obovate, solid; predominantly smooth; brown with spirals of irregular cream or yellow spots. *Spire:* last whorl obese; suture slightly channeled. *Sculpture:* microscopically spirally striate, the striae more pronounced near the base. *Aperture:* wide; longer than spire; outer lip with a prominent thickened nodule below the suture; effuse at base; columella with four or five oblique folds. *Color:* brown with spirals of irregular cream or yellow splashes which form a band of zigzags below the periphery of the last whorl; aperture white.

These miters are among the most commonly occurring of the shallow water Hawaiian miters, found in holes and fissures on fringing reefs, under rocks on solution benches, and in tide pools. They are the second most abundant predatory gastropods on solution benches where they apparently prey exclusively on sipunculids (Kohn, 1970). The miters extract the sipunculids from their burrows with the long proboscis and radula and convey the prey intact and alive to the stomach (Kohn, 1970). Four-lobed veligers are found in the plankton in October to January; they metamorphose when four whorls are complete, at a length of about 990 μm (J. B. Taylor, 1975).

M. litterata is distributed throughout the Indo-West Pacific, from East Africa to the Philippines, Ryukyu Islands, Micronesia, and Polynesia.

Mitra (Strigatella) pellisserpentis Reeve, 1844. Figs. 100 B; 104 F. (Synonyms: *Mitra samuelis* Dohrn, 1860; *?M. pallida* Pease, 1860; *M. astricta* Reeve, Sowerby, 1874; *M. reticulata* "Pease Ms", Garrett, 1880; *M. brumalis* Reeve, Sowerby, 1874; *M. dealbata* A. Adams, Tinker, 1952.) Length, 23 mm; diameter, 11 mm; aperture length, 14 mm. *Shell:* broadly fusiform; with spiral and axial striae; white to yellow. *Spire:* protoconch of at least two smooth, white whorls, the abapical larger than the apical whorl; teleoconch of rather flat whorls except for last whorl which is convex; suture impressed. *Sculpture:* variable — usually with spiral and axial striae but some shells are prominently granulose, others almost smooth; apical whorls clathrate. *Aperture:* narrow, somewhat flaring at base; longer than spire; outer lip crenulate; col-

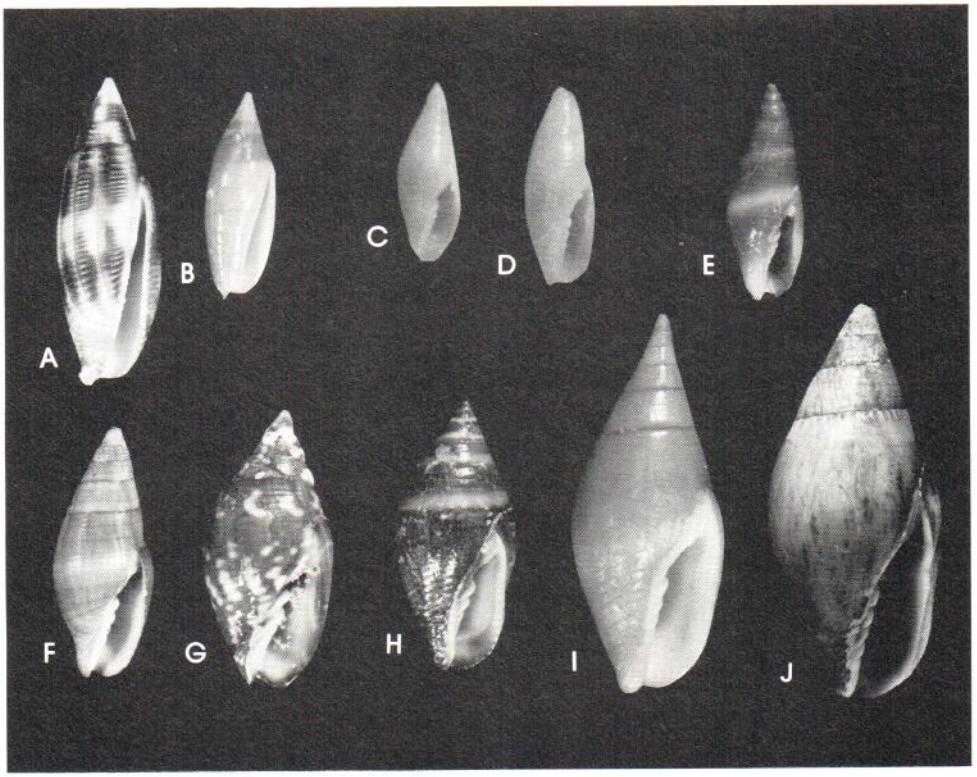


Figure 104.—**Mitridae.** *Mitra (Dibaphus).* A. *M. (D.) edentula,* length 31 mm. B. *M. (D.) multiplicata,* length 27 mm. *Mitra (Strigatella).* C, D. *M. (S.) saltata,* length 6 mm. E. *M. (S.) typha,* length 10 mm. F. *M. (S.) pellisserpentis,* length 23 mm. G. *M. (S.) litterata,* length 19 mm. H. *M. (S.) assimilis,* length 17 mm. I. *M. (S.) acuminata,* length 30 mm. J. *M. (S.) fastigium,* length 28 mm.

umella with four or five folds. *Color:* white to yellow, occasionally with dark brown striae; aperture white to light yellow; periostracum straw-colored.

These miters are common in tide pools and under rocks on fringing reefs. They produce vase-shaped egg capsules that are attached to the substratum at one end and closed by a plug at the other. Each contains up to 200 eggs, which hatch as veliger larvae (Ostergaard, 1950). A female deposits 60-70 capsules in succession over a period of 17-20 hours (Fretter, 1970).

An Hawaiian subspecies (*M. pellisserpentis astricta* Reeve, 1844) is distinguished by Cernohorsky (1976a), the Hawaiian shells differing from those of the widely distributed Indo-West Pacific form by the presence in some shells of brown threads or bands. This color feature seems variable and the subspecies is not recognized here.

Mitra (Strigatella) saltata Pease, 1865b. Fig. 104 C, D. (Synonyms: *Mitra alba* Pease, Pilsbry, 1921; *M. pellucida* Dall MS, J. Cate, 1963.) Length, 6 mm; diameter, 2 mm; aperture length, 4 mm. *Shell:* fusiform, slender; microscopically axially and spirally striate; white. *Spire:* protoconch of five conical, finely punctate white whorls oriented slightly at an angle to the spire; teleoconch of three slender, tapering, barely

convex whorls; suture linear. *Sculpture:* microscopic spiral and axial striae. *Aperture:* narrow; almost equal in length to spire; outer lip thickened centrally, flaring at base; columella with three or four folds. *Color:* white.

Shells of *M. saltata* are common in beach drift and the animals apparently live in shallow water in tide pools and to depths of 5 m. Shells are rarely found at depths greater than 20 m.

M. saltata is included in the synonymy of *M. typha* Reeve, 1844, by Cernohorsky (1976a). In the Hawaiian Islands the two species appear quite distinct. The shells of *M. saltata* are distinguished from those of *M. typha* by their white color, smaller size (mean length is 6 mm versus 10 mm in *M. typha),* the teleoconch of three whorls (there are four whorls in *M. typha*), sculpture of spiral and axial striae (the shells of *M. typha* are predominantly smooth), and the thick central portion of the outer lip. Shells of *M. saltata* are not uncommonly found in the Society Islands, and the species appears to be restricted in its distribution to the Tuamotu and Society Islands in addition to its occurrence in Hawaii.

Mitra (Strigatella) typha Reeve, 1845. Fig. 104 E. (Synonym: *Mitra micans* Reeve, Pilsbry, 1921.) Length, 10 mm; diameter, 3 mm; aperture length, 3 mm. *Shell:* fusiform, slender; smooth and shining; white spirally banded with brown. *Spire:* protoconch of five smooth, conical, white whorls of which one or more is inflated; teleoconch of four whorls; suture impressed. *Sculpture:* whorls smooth with growth striae only. *Aperture:* about equal in length to the spire; outer lip smooth; columella with three or four folds. *Color:* glossy white banded with one or two spirals of brown, one below the suture, the other at the periphery of the last whorl. Some shells may be predominantly brown with only an obsolete pale band. *Animal:* white.

Shells of *M. typha* are not uncommonly found at depths of from 20 to 100 m. Veligers are found in the plankton in March; they metamorphose when four and one-half to five whorls are complete, at a length of 1056 μm (J. B. Taylor, 1975).

M. typha is widely distributed throughout the Indo-West Pacific, from the Red Sea to the Philippines, southern Japan, and Polynesia.

Mitra (Dibaphus) edentula Swainson, 1823. Fig. 104 A. Length, 31 mm; diameter, 11 mm; aperture length, 21 mm. *Shell:* cylindrical; solid; finely spirally striate; white blotched with brown. *Spire:* teleoconch of five or six rather flat whorls; suture weakly impressed. *Sculpture:* finely spirally striate. *Aperture:* very narrow; longer than spire; outer lip thick, inflected centrally and flaring basally; columella with 6 to 11 weakly developed, oblique folds. *Color:* yellow-white with axially oriented brown blotches.

This miter is rarely found in the windward islands, but appears to be more common at Midway.

M. edentula occurs throughout the Indo-West Pacific, from Mauritius to the Philippines, southern Japan, Polynesia, and Clipperton Island.

Mitra (Dibaphus) multiplicata Pease, 1865b. Fig. 104 B. (Synonym: *Mitra paucilineata* "Dall," Tinker, 1952.) Length, 27 mm; diameter, 9 mm; aperture length, 18 mm. *Shell:* cylindrical; microscopically spirally striate; glossy, cream. *Spire:* pro-

toconch and teleoconch conical; whorls flatly convex; suture weakly impressed. *Sculpture:* microscopically finely spirally striate. *Aperture:* very narrow; longer than spire; outer lip thick, inflected centrally and flaring basally, sometimes finely crenulate; columella with six to 11 small, oblique folds. *Color:* glossy, cream to straw.

This is a rare species in Hawaiian waters, known only from two or three shells found on subtidal coral reefs on Hawaii and in beach drift on Midway.

M. multiplicata occurs throughout the Indo-West Pacific, from Mauritius to the Philippines, southern Japan and Polynesia.

Subfamily **Cylindromitrinae**

These miters are sand-dwellers and are found in shallow water elsewhere in their range, but none is common in Hawaii. The shell is fusiform-elongate to cylindrical-ovate, with spiral striae, and the aperture is narrow, longer than the spire. There is a single genus in the subfamily.

Pterygia crenulata (Gmelin, 1791). Fig. 105 D. Length, 21 mm; diameter, 8 mm; aperture length, 18 mm. *Shell:* cylindrical, solid; with evenly spaced spiral cords and axial grooves; white clouded with brown. *Spire:* short, projecting; suture channeled. *Sculpture:* equally spaced spiral grooves which separate flat spiral cords and are intersected by axial grooves. *Aperture:* narrow; much longer than spire; outer lip thick and crenulate; columella with seven to nine folds. *Color:* white or creamy white, irregularly clouded with red-brown.

This mitrid is uncommon, occasionally recorded from tide pools on Kauai and Hawaii and occurring at depths of from 8 to 26 m off Oahu and Maui.

This species is widely distributed in the Indo-West Pacific, ranging from the Red Sea to Okinawa, Micronesia, and Polynesia.

Pterygia fenestrata (Lamarck, 1811). Fig. 105 E. Length, 20 mm; diameter, 11 mm; aperture length, 17.5 mm. *Shell:* cylindrical-ovate, solid; with flat spiral cords cancellated by axial striae; gray-white. *Spire:* teleoconch of about four whorls, the last the largest; spire small and attenuate. *Sculpture:* close-set, flat, spiral cords cancellated by axial striae. *Aperture:* narrow, almost equal in length to the spire; outer lip thin but finely denticulate; columella with about nine folds; parietal callus raised. *Color:* gray-white.

Shells are known only from subfossil specimens dredged on fringing reefs on Molokai.

P. fenestrata is distributed throughout the Indo-West Pacific. The shells are distinguished from those of *P. pudica* by their cylindrical shape, flat spiral cords, and fewer columellar plaits, and from those of *P. crenulata* by their ovate shape and lack of punctations.

Pterygia pudica (Pease, 1860). Fig. 105 F. (Synonyms: *Mitra nuxavellana* Dohrn, 1860; *M. subrostrata* Sowerby, 1874; *?M. tabanula* Lamarck, Pilsbry, 1921.)

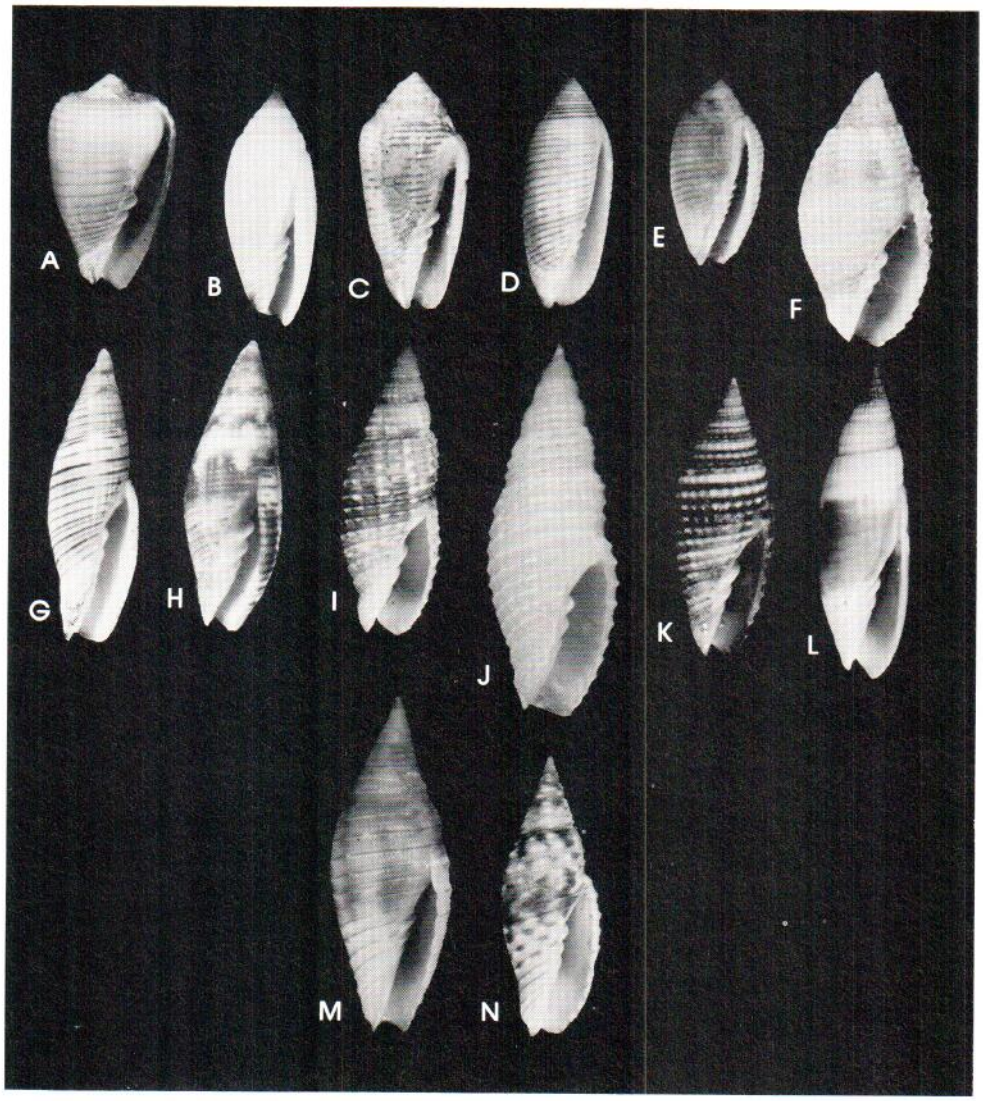


Figure 105.—A. *Imbricaria conovula*, length 16 mm. B. *I. olivaeformis*, length 13 mm. C. *I. punctata*, length 15 mm. D. *Pterygia crenulata*, length 25 mm. E. *P. fenestrata*, length 20 mm. F. *P. pudica*, length 15 mm. G. *Cancilla granatina*, length 20 mm. H. *Neocancilla clathrus*, length 21 mm. I. *N. papilio langfordiana*, length 30 mm. J. *Cancilla carnicolor*, length 13 mm. K. *Neocancilla waikikiensis*, length 12.5 mm. L. *Scabricola newcombii*, length 24 mm. M. *Subcancilla flammea*, length 10 mm. N. *S. foveolata*, length 20 mm.

Length, 15 mm; diameter, 7 mm; aperture length, 10 mm. *Shell:* fusiform-ovate, inflated; with broad spiral cords; white variegated with brown. *Spire:* attenuate, short; suture linear. *Sculpture:* prominent, broad spiral cords separated by narrow, finely axially striate interspaces. *Aperture:* longer than spire; outer lip thick and crenulate; columella with four or five folds. *Color:* white to gray-white irregularly variegated or banded with brown.

These miters are uncommon, occurring at depths of 16 to 80 m. Beachworn shells are occasionally found along the shores of northern beaches.

P. pudica is found in the Pacific Ocean, from New Caledonia to Polynesia.

Subfamily **Imbricariinae**

Members of this subfamily have shells which are elongate-ovate to conical, spirally striate, and the aperture is smooth within. These miters are sand-dwellers. In Hawaiian waters all species in the group are found subtidally, at depths of 3 to 200 m. The five genera may be keyed as follows:

1. Shell fusiform-elongate 2
   Shell conic to oliviform ..... *Imbricaria*

2. (1) Shell with spiral cords and axial striae or distinctly beaded 3
   Shell predominantly smooth ..... *Scabricola (Swainsonia)*

3. (2) With spiral cords and axial striae 4
   Sculpture decussate or beaded ..... *Neocancilla*

4. (3) Elevated spiral cords and prominent axial threads in the interspaces ..... *Subcancilla*
   With depressed spiral cords ..... *Cancilla*

Imbricaria conovula (Quoy and Gaimard, 1833). Fig. 105 A. Length, 16 mm; diameter, 8 mm; aperture length, 12 mm. *Shell:* obconic, broad at the shoulder; with fine, punctate spiral striae; cream tipped with dark purple. *Spire:* short, apex almost mamillate; last whorl prominently rounded at the shoulder; suture indistinct. *Sculpture:* fine, punctate spiral striae. *Aperture:* longer than the spire; outer lip straight and smooth; columella with five to six folds; parietal wall with a white callus which may spread onto the last whorl. *Color:* cream, siphonal canal dark purple.

These miters are found in sand at depths of from 3 to 60 m, often with *I. olivaeformis*.

I. conovula has a restricted Indo-West Pacific distribution, from the Cocos-Keeling Islands to Polynesia.

Imbricaria olivaeformis (Swainson, 1821). Figs. 100 G; 105 B. (Synonym: *Mitra olivellaeformis* Pilsbry, 1921.) Length, 13 mm; diameter, 6 mm; aperture length, 10 mm. *Shell:* obovate, slender; smooth or finely punctate; cream or yellow, apex and base dark purple. *Spire:* protoconch of three and one-half conical, dark purple whorls which project above the teleoconch; suture moderately impressed. *Sculpture:* variable — smooth or with fine punctate spiral striae; apical whorls clathrate. *Aperture:* outer lip thick and smooth; longer than spire; columella with about 8 folds. *Color:* creamy white or yellow, apex and base dark violet or purple, aperture yellow.

These miters are sand-dwellers, found at depths of 10 to 80 m off Oahu. Veligers occur in the plankton from May through August; they metamorphose when three to four whorls are complete, at a length of 1040 μm (J. B. Taylor, 1975).

This species occurs throughout the Indo-West Pacific, from Mauritius to Polynesia.

Imbricaria punctata (Swainson, 1821). Fig. 105 C. Length, 15 mm; diameter, 7 mm; aperture length, 12 mm. *Shell:* obconic, broadly shouldered; with punctate spiral striae; cream. *Spire:* acutely tapered, short; last whorl broad at the shoulder; suture indistinct. *Sculpture:* fine punctate spiral striae on an otherwise smooth shell. *Aperture:* straight; much longer than spire; outer lip smooth; columella with six or seven folds. *Color:* creamy white to light yellow.

These miters are sand-dwellers, found at depths of 10 to 160 m off Oahu and at lesser depths off Maui and Hawaii.

I. punctata occurs throughout the Indo-West Pacific from Mauritius to Polynesia.

Cancilla (Domiporta) sp. cf. *carnicolor* (Reeve, 1844). Fig. 105 J. Length, 11 mm; diameter, 3.5 mm; aperture length, 5 mm. *Shell:* fusiform, slender; with sharp spiral threads bisected by axial striae; white, spiral threads brown, apex pink. *Spire:* protoconch of four inflated, conical, pink whorls; teleoconch of five slightly inflated whorls; suture distinct, ledged. *Sculpture:* sharp, elevated spiral threads, ten on the last whorl, four on the penultimate whorl, separated by wide, shallow interspaces; spiral threads and interspaces overrun by axial striae which cut the threads into obsolete granules and the interspaces into faintly cancellate rectangles. *Aperture:* narrow; slightly shorter than the spire; outer lip barely crenulate; columella with three oblique folds. *Color:* white, spiral threads brown, apex and tip of siphonal canal pink.

These delicate, small miters are rare, dredged from depths of 200 m.

C. carnicolor was described from the Philippines. The Hawaiian shells are only tentatively referred to the species: they are smaller than the types (which are about 30 mm in length), the sculpture is neater and more regular than it is in the types although it is similar to the sculpture on the early whorls of the types, and the pink protoconch and brown outlines on the spiral threads are distinctive.

Cancilla (Domiporta) granatina (Lamarck, 1811). Figs. 100 E; 105 G. (Synonyms: *Mitra langfordi* Pilsbry, 1921; *M. missa* Dall MS, J. Cate, 1962a; *M. peasei* J. Cate, 1962a, non Dohrn, 1861.) Length, 20 mm; diameter, 6 mm; aperture length, 11 mm. *Shell:* fusiform, inflated; with spiral cords and threads; white, spiral cords brown. *Spire:* protoconch of three and one-half conical, glassy pink whorls; teleoconch of seven convex whorls, whorls angulate at the suture which is impressed. *Sculpture:* elevated spiral cords; interstices with one or two intermediate spiral threads and axial growth striae. *Aperture:* wide; only slightly longer than the spire; outer lip crimped at the edge; columella with four or five folds. *Color:* creamy white, spiral cords brown; occasionally with two or three dark brown spiral cords giving the impression of two darker transverse bands on the last whorl; aperture white.

These miters live in sand at depths of from 12 to 500 m. Veligers are found in the plankton in March; they metamorphose when four and one-half to five whorls are complete, at a length of 1420 μm (J. B. Taylor, 1975).

This species is widely distributed in the Indo-West Pacific, from the Red Sea to the Philippines, southern Japan, the Ryukyu Islands, and Polynesia.

Neocancilla clathrus (Gmelin, 1791). Fig. 105 H. (Synonyms: *Mitra emersoni* Pilsbry, 1921.) Length, 21 mm; diameter, 7 mm; aperture length, 12 mm. *Shell:* fusiform; with flat spiral cords and deep axial grooves; white, blotched and banded with brown. *Spire:* protoconch of 5 microscopically punctate pink whorls, slightly eccentric to the spire axis; spire produced, of convex whorls with the suture impressed. *Sculpture:* barely elevated, somewhat flattened spiral cords which are steplike in profile and one or two smaller, intermediate spiral threads; deep axial grooves crossing the spiral sculpture forming irregular squares. *Aperture:* narrow; longer than the spire; outer lip crimped; columella with four folds. *Color:* white, apical whorls with a spiral row of brown blotches next to suture; last whorl with a broad brown peripheral band which is undulate and a narrower band toward the base.

These miters occur at depths of from 2 to 50 m.

N. clathrus is widely distributed in the Indo-West Pacific, ranging from Aden and the Persian Gulf to southern Japan, Okinawa, and Polynesia.

Neocancilla papilio langfordiana J. Cate, 1962c. Fig. 105 I. (Synonym: *Mitra sphaerulata* Martyn, Garrett, 1880.) Length, 30 mm; diameter, 10 mm; aperture length, 14 mm. *Shell:* fusiform, solid; with beaded spiral cords; creamy white mottled with red-brown. *Spire:* protoconch of two and one-half smooth, pink whorls; whorls of teleoconch convex, separated by an impressed suture. *Sculpture:* regularly spaced beaded spiral cords with finely striate interspaces, the beaded effect created by the intersection of the spiral cords and axial striae. *Aperture:* straight, narrow; shorter than spire; outer lip crenulated by the external sculpture; columella with four or five folds. *Color:* creamy white, irregularly mottled with red-brown, nodules alternately white and brown.

These miters are found at depths of from 10 m to 120 m.

N. papilio is widely distributed in the Indo-West Pacific, from Mauritius and the Gulf of Aden to the Philippines, Okinawa, Micronesia, and Polynesia. The Hawaiian subspecies is distinguished by its smaller size, less brilliant coloration, white aperture, and weaker sculpture.

Neocancilla waikikiensis Pilsbry, 1921. Figs. 100 F; 105 K. (Synonym: *Mitra colpophila* Dall MS, Cate, 1963.) Length, 12.5 mm; diameter, 4.8 mm; aperture length, 6.7 mm (type dimensions). *Shell:* fusiform; with nodulose spiral cords; pale brown with darker spirals and white nodules. *Spire:* protoconch of four and one-half straight, conical, glassy white whorls; last whorl moderately convex; suture inconspicuous. *Sculpture:* prominent spiral cords intersected by axial ribs forming spiral rows of nodules where cords and ribs intersect; in larger shells there may be smaller intermediate spiral cords. *Aperture:* narrow; equal in length or less than half the length of spire; outer lip finely crenulate; columella with three to five folds. *Color:* rather variable — light fawn, pale brown or rusty brown with darker spiral bands and white nodules.

These miters are very common at depths of from 20 to 200 m. Veligers are found

in the plankton in February; metamorphosis occurs when five to five and one-quarter whorls are complete, at a length of 1500 to 1550 μm (J. B. Taylor, 1975).

N. waikikiensis is endemic to the Hawaiian Islands.

Scabricola (Swainsonia) newcombii (Pease, 1869b). Figs. 100 H; 105 L. Length, 24 mm; diameter, 8 mm; aperture length, 13 mm. *Shell:* obovate, solid; last whorl predominantly smooth; white spirally banded with brown. *Spire:* slender and projecting; protoconch of three and one-half cream whorls slightly eccentric to the axis of the spire; teleoconch of four or five barely convex whorls separated by a linear suture. *Sculpture:* apical whorls with punctate spiral grooves crossing smooth axial ribs; the same sculpture is present near the suture of the last whorl but the remainder of the shell is smooth except for a few spiral striae. *Aperture:* about half the length of the shell or slightly longer; outer lip smooth; columella with five folds. *Color:* white with a broad brown spiral band on the last whorl.

S. newcombii is common at depths of from 8 to 100 m. Four-lobed veliger larvae are found in the plankton from May through August; they metamorphose when three whorls are complete, at a length of 900 μm (J. B. Taylor, 1975).

This species appears to be endemic to the Hawaiian Islands. It resembles *S. bicolor* (Swainson, 1824) from Mauritius and East Africa, but neither species is found in the intervening region.

Subcancilla flammea (Quoy and Gaimard, 1833). Fig. 105 M. Length, 10 mm; diameter, 3 mm; aperture length, 5 mm. *Shell:* fusiform, slender; with elevated spiral cords between which are fine axial ribs intersected by spiral threads; white, spiral cords usually brown and spirally banded with brown. *Spire:* protoconch of four and one-half smooth, conical whorls; spire attenuate; last whorl inflated; suture impressed. *Sculpture:* prominent, elevated spiral cords, the interspaces of greater diameter and with fine axial ribs intersected by two or three spiral threads producing a somewhat beaded effect. *Aperture:* narrow, about equal in length to the spire; outer lip crenulate; columella with four or five folds. *Color:* white, spiral cords often brown, and on the last whorl with axial brown blotches below the suture and in a spiral about the periphery.

These miters are common, dredged with *S. foveolata* at depths of from 40 to 200 m.

S. flammea was described from the Philippine Islands and ranges through the Indo-West Pacific from Mauritius to Fiji. The shells are distinguished from those of *S. verrucosa foveolata* by their smaller size and finer sculpture.

Subcancilla foveolata (Dunker, 1858). Fig. 105 N. (Synonym: *Mitra foveolata* "Hanley" (pars), Sowerby, 1874 (Pl. 359, Fig. 370 only); *Subcancilla verrucosa foveolata* Dunker, Cernohorsky, 1977b.) Length, 20 mm; diameter, 7 mm; aperture length, 12 mm. *Shell:* fusiform, slender; with elevated spiral cords between which are straight axial riblets; white variously splashed with red-brown. *Spire:* protoconch of four smooth, conical whorls; spire attenuate, last whorl inflated; suture impressed. *Sculpture:* prominent, elevated spiral cords, the interspaces of greater diameter and with straight axial riblets; an additional small, somewhat nodulose spiral thread sometimes crosses the riblets and coarse axial folds occasionally roughen the shell. *Aper-*

ture: narrow; longer than spire; outer lip crenulate; columella with four or five folds. *Color:* white, ornamented with an interrupted red-brown band on the periphery of the last whorl, spots of the same color at the suture, and dark red-brown dashes on spiral cords; some specimens with obsolete flamelike axial zones.

These miters are common at depths of from 40 to 200 m. Veligers are found in the plankton in January; they metamorphose when four whorls are complete, at a length of 1010 μm (J. B. Taylor, 1975).

Cernohorsky (1977) recognizes these Hawaiian miters as an endemic subspecies of *S. verrucosa* (Reeve, 1845), basing his interpretation on shell characters. The radula, however, is quite different from that of specimens of *S. verrucosa* (figured by Cernohorsky, 1970b), and more nearly like that of *S. interlirata* (Reeve, 1845) (figured by Cernohorsky, 1970b). Because of the distinctive radular pattern, *S. foveolata* is here recognized as a full species, endemic to the Hawaiian Islands. Dunker described the species from an unknown locality; Sowerby (1874) attributed it to Hawaii.

Additional Records

A recently described species, *Neocancilla kayae* Cernohorsky, 1978a, is apparently endemic to the Hawaiian Islands, found at depths of 120 to 200 m. The shells are about 9 mm long, 3.5 mm in diameter, elongate-ovate, with deeply incised suture and regular rows of round, close-set nodules, and white, ornamented with red-brown blotches.

One species was erroneously described from the Hawaiian Islands, *Mitra plebeia* Dohrn, 1860, a synonym of *M. latruncularia* Reeve, 1844 (Cernohorsky, 1970b). *M. sectilis* Pease, 1868a, is too briefly described to permit positive identification. Other species questionably referred to Hawaii but for which there are no authentic records of occurrence include *Mitra (Strigatella) ancillides* Broderip (J. Cate, 1963); *M. (S.) paupercula* (Sowerby, 1875) (Cernohorsky, 1976a from the Honolulu dredge harbor spoils); *M. cardinalis* Gmelin, (Garrett, 1880), and *Zierliana anthracina* (Reeve) (Garrett, 1880).

Family **Costellariidae**

The distinguishing feature of the shells of the costellarids is the lirate aperture: the outer lip is sculptured by a series of fine cords which extend from the outer lip into the aperture. The shells are predominantly axially sculptured, although in some species (for example, *Vexillum cancellarioides* and *Thala)* the shell is distinctly nodulose or granular. Two genera are recognized here: *Thala,* distinguished by its fusiform, beaded shells; and *Vexillum* with two subgenera, *Costellaria* and *Pusia.* The shells of costellarids are so variable in shape and sculpture, however, that subgeneric placement is often difficult, and species assigned to one or the other of the subgenera may be transferred when information on radula or habits of the animal is available.

Like the mitrids, the costellarids are carnivorous. The pleurembolic proboscis is extremely long and flexible, and may be extended at least the length of the individual's shell. The anatomy and mode of feeding of *Thala floridana,* a small shallow-water form from the Gulf of Mexico and parts of the Caribbean, have been described

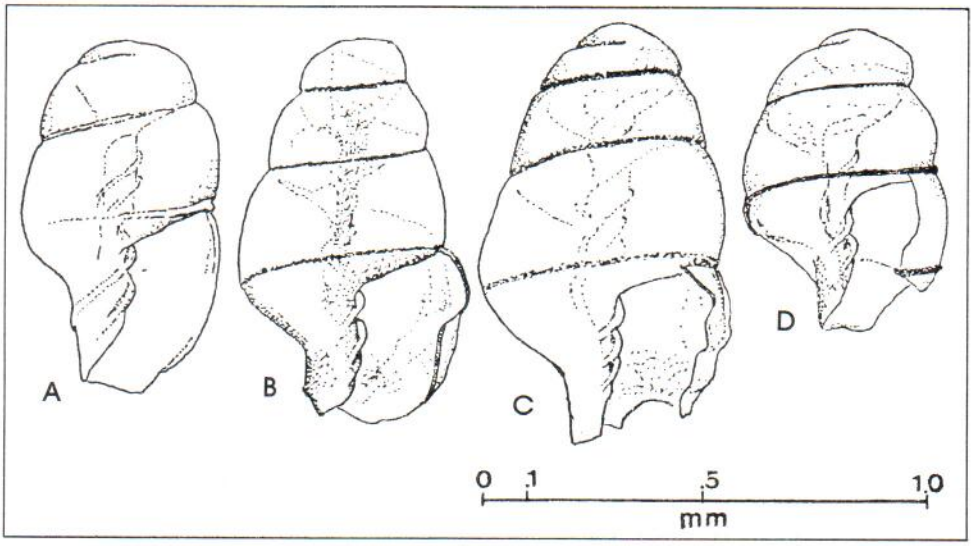


Figure 106.—A. Premetamorphic protoconch, *Vexillum (Costellaria) bellum*. B. Premetamorphic protoconch, *Vexillum (Pusia) lautum*. C. Premetamorphic protoconch *V. (P.) tusum*. D. Premetamorphic protoconch *V. (C.) interstriatum*.

(Maes and Raeihle, 1975). These mollusks feed on small gastropods which are killed by a venom probably secreted by the accessory salivary glands (there is no venom gland homologous to that in *Conus*); after the prey is paralyzed, the mollusk feeds by sucking up tissues through the proboscis.

The egg capsules are hemispherical (Ponder, 1972b; Maes and Raeihle, 1975). In *Thala floridana* the young snails crawl out of their capsules about 23 days after oviposition, and the life span of this 6.5 mm long snail is at least six years (Maes and Raeihle, 1975).

Costellarids, like the mitrids, are both rock- and sand-dwellers. There are in Hawaii, however, relatively fewer shallow-water costellarids than mitrids: excluding the six costellarid species known only from subfossil or beachworn shells, 25 or 66 percent of the costellarids are common in the intertidal and to depths of 20 m, and 13 or 34 percent are found at depths greater than about 50 m. (In the Mitridae 33 or 78 percent are found in shallow water and 10 or 24 percent at depths of more than 50 m.)

I record 44 species in the family Costellariidae in Hawaii, three in the genus *Thala* and 21 and 20 respectively in the subgenera *Costellaria* and *Pusia*. In contrast to the family Mitridae which has a predominantly Indo-West Pacific distribution, the members of the Costellariidae show a strong tendency to be restricted in their occurrence to the Pacific Basin: 29 or 66 percent of the costellarids are reported only from the Pacific Basin (including Hawaii). Endemism or presumed endemism is about the same as in the Mitridae, with 6 or 14 percent of the costellarids reported only from Hawaii.

In the following descriptions all ranges apart from the Hawaiian records are from Cernohorsky (1965; 1970b).

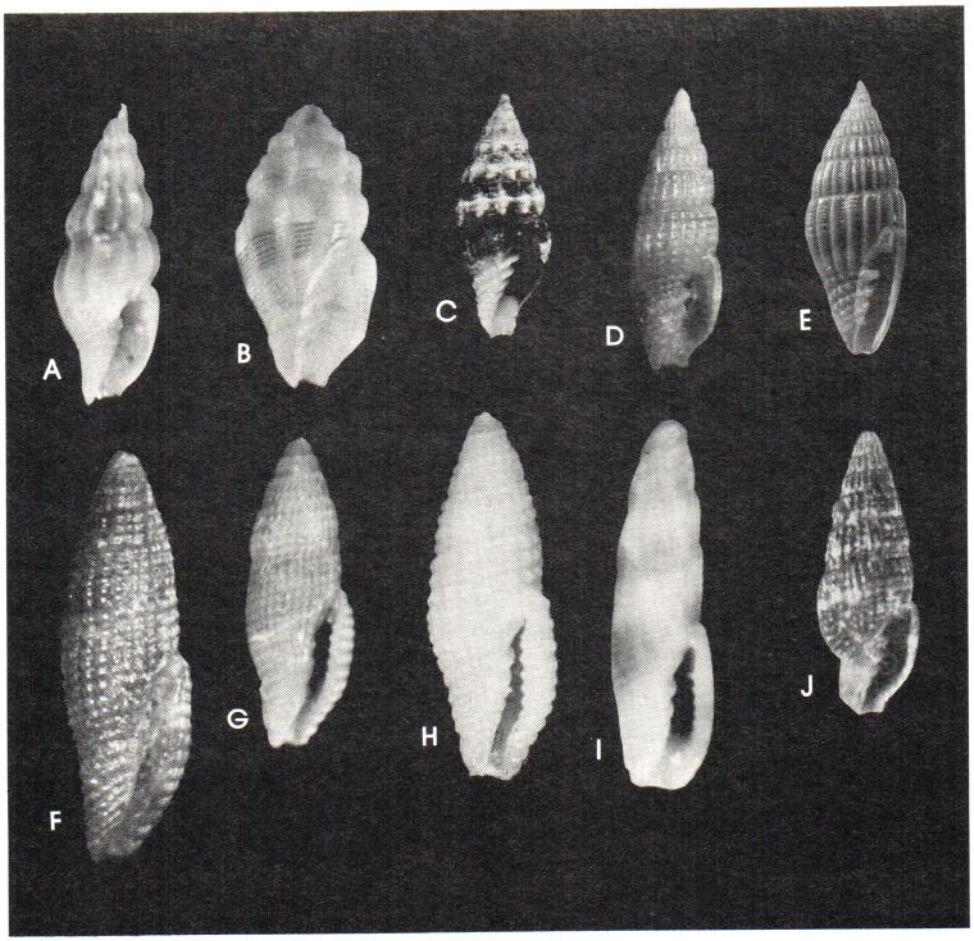


Figure 107.—**Costellariidae** and **Volutomitridae.** A. *Vexillum (Costellaria) castum,* length 5 mm. B. *V. (C.) interruptum,* length 10 mm. C. *V. (C.) leucozonias,* length 15 mm. D. *V. (C.) micra,* length 6.5 mm. E. *V. (C.) fortiplicatum,* length 12 mm. F, G. *Thala milium,* length 6 mm. H. *T. todilla,* length 7 mm. I. *T. exilis,* length 6.5 mm. J. *Volutomitra pailoloana,* length 30 mm.

Thala exilis (Reeve, 1845). Fig. 107 I. Length, 6.5 mm; diameter, 1.7 mm. *Shell:* fusiform-cylindrical, slender; beaded with fine axial and spiral threads; light pink splashed with brown. *Spire:* teleoconch of four or five straight-sided whorls; suture barely impressed. *Sculpture:* evenly spaced axial and spiral threads, forming minute, regularly arranged beads at their junctions. *Aperture:* narrow, slightly constricted centrally; outer lip finely denticulate; columella with three folds. *Color:* beachworn shells light pink splashed with brown, the darker color in a prominent spiral band on the last whorl.

Beachworn shells are rare in beach drift on north shore beaches on Oahu.

T. exilis was described from the Philippine Islands, and the species appears to occur through the Indo-West Pacific from Ceylon (as *T. ceylonanica* Preston, 1904) to the "China Seas" (as *T. jaculanda* (Gould, 1860)).

Thala milium (Reeve, 1845). Fig. 107 F, G. Length, 6 mm; diameter, 2 mm; aperture length, 3 mm. *Shell:* fusiform-cylindrical; slender; with axial and spiral threads forming beads at their junctions; purple. *Spire:* teleoconch of four or five rather straight-sided whorls; suture linear. *Sculpture:* numerous, fine axial ribs overridden by spiral threads, forming beads at the junctions; base with beaded cords. *Aperture:* narrow, slightly constricted centrally; outer lip denticulate; columella with four folds. *Color:* deep purple in live-collected shells, lavender in worn shells.

These shells are rare, found at depths of about 20 m in rubble.

T. milium was described from the Philippine Islands.

Thala todilla (Mighels, 1845). Fig. 107 H. Length, 7 mm; diameter, 2.5 mm; aperture length, 4 mm. *Shell:* fusiform-cylindrical; slender; with axial and spiral threads forming prominent beads at the junctions; white. *Spire:* protoconch of four smooth, white, conical whorls; teleoconch of about seven straight-sided whorls; suture linear. *Sculpture:* numerous, fine axial ribs overridden by spiral grooves and threads producing a beaded effect. *Aperture:* narrow, slightly constricted centrally; outer lip denticulate; columella with four folds. *Color:* white, occasionally cream with minute brown spots.

Shells are common in shallow water under rocks in tide pools, on fringing reefs, and in beach drift.

T. todilla was described from the Hawaiian Islands and also occurs in the Ryukyu Islands (as *T. secalina* (Gould, 1860)).

Vexillum (Costellaria) adamsianum Cernohorsky, 1978a. Fig. 108 A, B. (Synonym: *Mitra agria* Dall MS, J. Cate, 1963, as a synonym of *Vexillum xenium* Pilsbry, 1921.) Length, 13.7 mm; diameter, 4.7 mm; aperture length, 5 mm (holotype dimensions). *Shell:* elongate-ovate; with keeled axial ribs and low spiral cords; white blotched with dark red-brown. *Spire:* protoconch of three and one-half conical, white whorls; teleoconch of five to seven slightly convex whorls, angulate at the suture. *Sculpture:* keeled, usually straight axial ribs, 13 to 17 on the penultimate whorl, and distinct, low spiral cords crossing the axial ribs and notching the summit. *Aperture:* slightly longer or shorter than spire; lirate within; columella with four or five oblique folds. *Color:* white, densely blotched with rectangular or quadrate blotches of dark brown or red brown, the blotches in two spiral bands on the last whorl and a single spiral on the apical whorls; aperture tinted rose or violet.

Shells are found at depths of about 150 m in *Pinna* beds and in sand and rubble.

V. adamsianum was described from the Hawaiian Islands but shells have also been found in Tahiti at depths of 10 to 12 m (Cernohorsky, 1978a).

Vexillum (Costellaria) bellum (Pease, 1860). Figs. 106 A; 108 M. Length, 25 mm; diameter, 7 mm; aperture length, 11 mm. *Shell:* fusiform, slender; with barely beaded axial ribs and flat spiral threads; cream with rectangular red-brown spots. *Spire:* protoconch of one and one-half smooth, white whorls; teleoconch of eight or nine barely convex whorls; suture shallow. *Sculpture:* axial ribs straight, barely keeled, the interspaces of greater diameter than the ribs, shallow and often with a smaller intercalary axial thread; spiral threads flat, lightly indenting the axial ribs and produc-

ing a slightly beaded effect. *Aperture:* narrow, outer lip barely effuse; lirate within; columella with four or five folds. *Color:* cream spirally banded with two rows of red-brown spots on the last whorl, one below the suture, the other below the periphery and a single row of spots on the apical whorls; worn shells often white and barely flecked with brown.

These costellarids are common at depths of 5 to 100 m. Four-lobed veliger larvae are found in the plankton in August; they metamorphose when two and three-quarters whorls are complete, at a length of 800 μm (J. B. Taylor, 1975).

V. bellum was described from the Hawaiian Islands and also occurs in Samoa and the Tuamotus. The shells are distinguished from those of *V. macrospirum* by the straight, keeled axial ribs and wide, shallow interspaces between the ribs.

Vexillum (Costellaria) castum (H. Adams, 1872). Fig. 107 A. Length, 5 mm; diameter, 2 mm. *Shell:* fusiform, with bold, keel-like axial ribs and spiral striae; white. *Spire:* protoconch of three and one-half conical, convex whorls; teleoconch of four inflated whorls; suture distinct, deep and incised. *Sculpture:* bold, keel-like axial ribs, about 14 on the last whorl, separated by their own diameter, the interspaces finely spirally striate. *Aperture:* broadly open; lirate within; outer lip thin; columella with three plaits. *Color:* glistening white.

These costellarids are common at depths of from 10 to 100 m.

V. castum was described from the Red Sea.

Vexillum (Costellaria) collinsoni (A. Adams, 1853a). Fig. 108 N. (Synonyms: *Mitra polycymata* Dall MS, J. Cate, 1963; *M. iota* Dall MS, J. Cate, 1963.) Length, 14 mm; diameter, 6 mm; aperture length, 6 mm. *Shell:* fusiform, slender; with narrow axial ribs crossed by spiral threads; brown spirally banded with white. *Spire:* protoconch of one and one-half or two smooth whorls; teleoconch of six or seven slightly convex whorls separated by a distinct suture. *Sculpture:* slender, slightly sinuous axial ribs (14 to 20 on the last whorl), the interspaces broader than the ribs and spirally striate. *Aperture:* narrow; about one-third the length of the spire; outer lip smooth; lirate within; columella with about four folds. *Color:* brown or red-brown with a single white band on the apical whorls and one or two narrow white bands on the last whorl.

Shells of *V. collinsoni* are rare, dredged from depths of 80 to 100 m.

This species was described from Japan and also occurs in Indonesia, the Philippines, and Fiji.

Vexillum (Costellaria) corbiculum (Sowerby, 1870). Fig. 108 K. Length, 15 mm; diameter, 5 mm; aperture length, 7.5 mm. *Shell:* fusiform-obese; with fine axial ribs and finer spiral striae; cream with one row of chocolate brown patches below the suture and indistinctly outlined brown bands. *Spire:* teleoconch of six slightly inflated whorls; suture impressed. *Sculpture:* fine axial ribs separated one from the other by about their own diameter and with impressed spiral striae between. *Aperture:* narrow, less than one-half the length of the spire; lirate within; columella with four folds. *Color:* cream spirally banded with darker tones and spotted with brown on the shoulder.

These costellarids are rare, found at depths of about 60 m.

V. corbiculum was described from Mauritius.

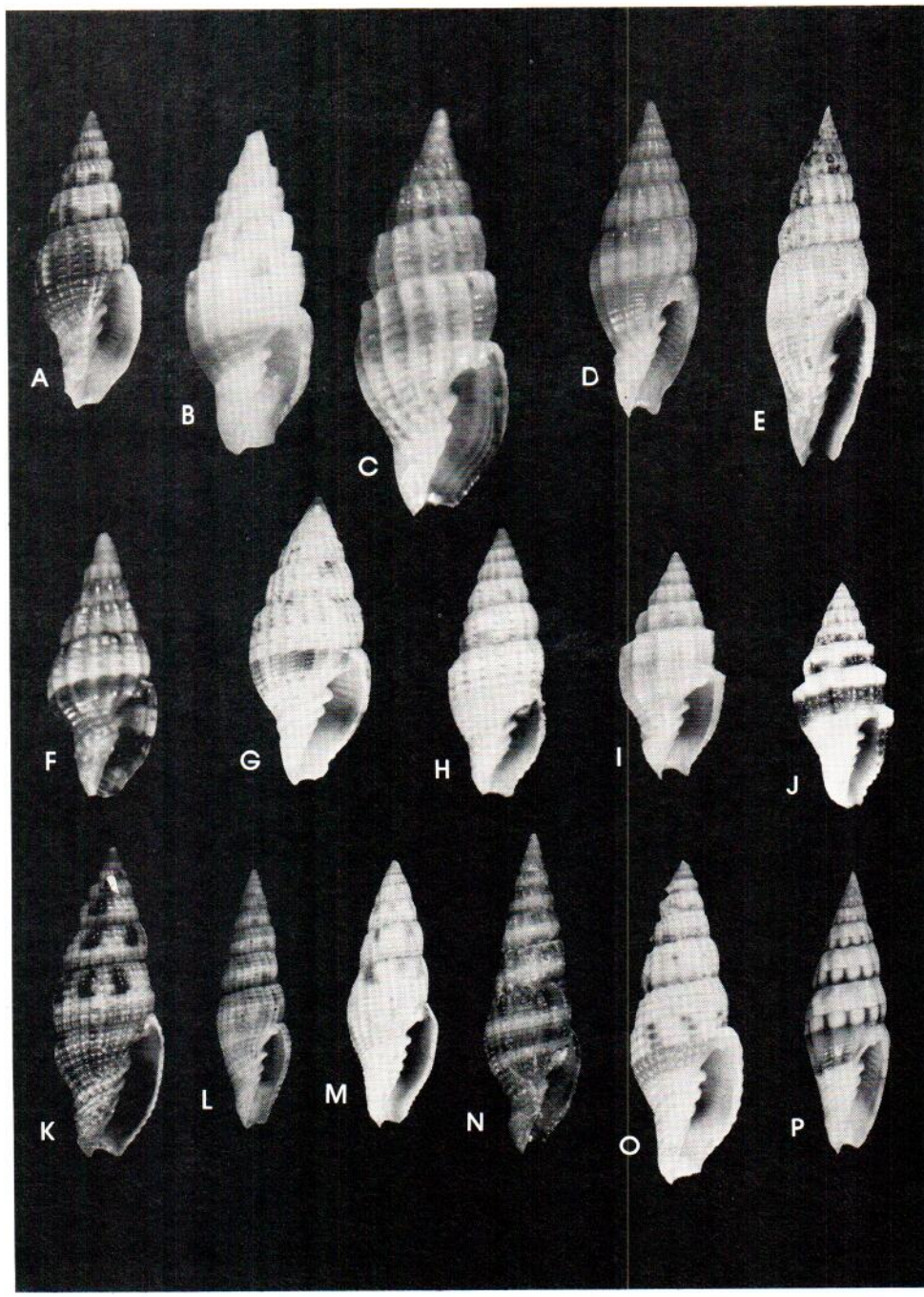


Figure 108.—**Costellariidae.** *Vexillum (Costellaria).* A, B. *V. (C.) adamsianum,* length 10 mm. C. *V. (C.) wolfei,* length 7 mm. D. *V. (C.) rufofilosum,* length 10 mm. E. *V. (C.) radix,* length 20 mm. F. *V. (C.) diutenera,* length 4 mm. G. *V. (C.) xenium,* length 26 mm. H. *V. (C.) modestum,* length 15 mm. I. *V. (C.) pacificum,* length 15 mm. J. *V. (C.) unifasciatum,* length 28 mm. K. *V. (C.) corbiculum,* length 15 mm. L. *V. (C.) macrospirum,* length 27 mm. M. *V. (C.) bellum,* length 25 mm. N. *V. (C.) collinsoni,* length 14 mm. O. *V. (C.) filistriatum,* length 17 mm. P. *V. (C.) interstriatum,* length 21 mm.

Vexillum (Costellaria) cosmani Kay, new species. Fig. 110 C. Length, 8 mm; diameter, 2.5 mm; aperture length, 3 mm (Holotype). Length range of three shells, 6 to 8 mm. *Shell:* cylindric-fusiform; with beaded spiral cords; white. *Spire:* protoconch of three and one-half inflated, conical, slightly eccentric white whorls, narrower than teleoconch and sharply delimited, appearing almost styliform; teleoconch of six inflated whorls; suture barely impressed and whorls barely distinguished one from the other. *Sculpture:* flat spiral cords, about 12 on the last whorl, cut by axial grooves of lesser diameter than the cords; base with four faintly beaded cords. *Aperture:* narrow, less than one-half the length of the spire; lirate within; columella with four folds; parietal nodule prominent. *Color:* white.

These shells are found in sediments at depths of 10 to 66 m.

Type locality: Kealakekua Bay, Hawaii, in sand and rubble at a depth of 10 m. *Holotype:* B. P. Bishop Museum No. 9808. *Paratypes:* B. P. Bishop Museum; R. Salisbury collection.

These small, white, cylindro-fusiform costellarids are distinguished by their cylindrical shape, flat spiral cords, smaller size, and white color from the shells of *V. (C.) micra* (Pilsbry). This species is named for Mr. Dieter Cosman who participated in many of the dredging activities which have resulted in much new information on Hawaiian deep water mollusks.

Vexillum (Costellaria) diutenera (Hervier, 1898). Fig. 108 F. (Synonym: *Mitra eruda* Dall MS, J. Cate, 1963.) Length, 4 mm; diameter, 2.5 mm; aperture length, 3 mm. *Shell:* fusiform-ovate; turreted; with prominent axial ribs and fine spiral striae; white spirally banded on the apical and abapical parts of the last whorl with dark red brown. *Spire:* protoconch of one and one-half smooth, light brown whorls; teleoconch of five somewhat convex, angulate whorls; suture deep. *Sculpture:* prominent, straight, keeled axial ribs, the interspaces of almost equal diameter and spirally lineated; base with four cords, the apical cord slightly beaded. *Aperture:* narrow; lirate within; about half the length of the spire; columella with three or four folds. *Color:* variable — white banded apically and abapically with russet brown on the last whorl in live-collected specimens; russet brown, reddish, or cream with a faint indication of a darker band in beachworn shells.

These gastropods are found at depths of 10 to 100 m. The shallow-water shells seem to be larger and broader than the deep-water forms.

V. diutenera was described from Lifu, Loyalty Islands. Hervier (1898) described three costellarid species with shells superficially alike from Lifu: *Mitra (Pusia) diutenera, M. (P.) roseotinctum,* and *M. (P.) rhodochroa*. The last-named, with its bold axial ribs and spirals of shades of rose, is clearly a synonym of *Vexillum (Pusia) rubrum* (Broderip, 1836). Cernohorsky (1970b) lists *M. (P.) diutenera* as a synonym of *M. (P.) roseotinctum*. The Hawaiian shells have been compared with Hervier's types and are distinguished as *Vexillum (Costellaria) diutenera* distinguished from the shells of *V. (C.) roseotinctum* by their more turreted form, red to brown rather than rosy color, and color pattern of a distinctive dark band around the base of the last whorl.

Vexillum (Costellaria) filistriatum (Sowerby, 1874). Fig. 108 O. Length, 17 mm; diameter, 5.5 mm; aperture length, 9 mm. *Shell:* fusiform, slender, slightly turreted;

cancellated by axial ribs and nodular spiral threads; off-white, last whorl peripherally banded with brown. *Spire:* attenuate; teleoconch of seven or more slightly convex whorls; suture barely channeled. *Sculpture:* axial and spiral sculpture of about equal strength; axial ribs barely sinuous, nodulose where they are intersected by the spiral threads. *Aperture:* straight; equal in length to the spire; lirate within; columella with about five folds; canal slightly recurved. *Color:* off-white to fawn, the last whorl peripherally banded with dark brown and occasionally with descending axial streaks.

Shells of *V. filistriatum* are uncommon, dredged at depths of from 30 to 130 m.

This species is distributed in the Pacific from the Philippines to Fiji.

Vexillum (Costellaria) fortiplicatum (Pease, 1868b). Fig. 107 E. (Synonym: *Vexillum kewaloensis* J. Cate, 1963.) Length, 12 mm; diameter, 5 mm; aperture length, 5 mm. *Shell:* fusiform, attenuate at the extremities; with narrow, rounded axial ribs and spiral striae; labrum lirate; red-brown. *Spire:* protoconch of one and one-half conical, smooth, brown whorls; teleoconch of about 8 whorls; suture distinct but not deep. *Sculpture:* narrow, elegant axial ribs, the interspaces subequal and with spiral striae; nodulose spiral cords at base. *Aperture:* narrow; about half the length of the spire; lirate within; columella with four folds; parietal wall with a callosity. *Color:* red-brown axial ribs, spire and base off-white. Beachworn specimens show a faint lighter peripheral spiral line on the last whorl.

Shells of *V. fortiplicatum* are known largely from subfossil specimens dredged in Honolulu Harbor and collected in beach drift on Laysan; a single live specimen was dredged by the *Pele* at a depth of 300 m in sand.

This species appears to be restricted in its distribution to the Pacific, occurring from the Loyalty Islands to the Tuamotus.

Vexillum (Costellaria) interruptum (Anton, 1839). Fig. 107 B. (Synonym: *Vexillum nodulosa* Pease, Pilsbry, 1921.) Length, 10 mm; diameter, 4 mm. *Shell:* fusiform, turreted; with large nodular axial ribs and fine spiral striae; white with short brown transverse lineations. *Spire:* protoconch of at least three conical pink whorls; teleoconch obtuse, turreted; suture shallow. *Sculpture:* large convex axial ribs nodular at the periphery and the interspaces with fine spiral striae. *Aperture:* narrow; shorter than spire; outer lip thick; lirate within; columella with about four folds. *Color:* white with short, interrupted, brown spiral lines below the periphery of the whorls.

Shells are common in beach drift and living animals in sand at depths of 10 m. Veligers are found in the plankton from March through July; they metamorphose when about three whorls are complete, at a length of 900 μm (J. B. Taylor, 1975).

This species is distributed through the Pacific from the Philippines to Micronesia (Caroline Islands) and Polynesia.

Vexillum (Costellaria) interstriatum (Sowerby, 1870). Figs. 106 D; 108 P. (Synonym: *Vexillum thaanumi* Pilsbry, 1921.) Length, 21 mm; diameter, 8 mm; aperture length, 11 mm. *Shell:* fusiform, turreted; with low, rounded axial ribs and punctate spiral grooves; white with a brown spiral at the periphery of the last whorl. *Spire:* nine whorls exclusive of the protoconch; suture distinct. *Sculpture:* rounded axial ribs, the interspaces of lesser diameter and spirally striate; base with two spiral

cords. *Aperture:* narrow; longer than spire; outer lip smooth; lirate within; columella with about five folds. *Color:* white to cream with a broad brown spiral band below the periphery of the last whorl, apical whorls with a brown spiral line.

Shells of *V. interstriatum* are uncommon, found at depths of from 8 to 100 m.

This species was described from the China Seas, but confirmed records are known only from Palau and Fiji in addition to the Hawaiian Islands.

Vexillum (Costellaria) leucozonias Deshayes in La Borde and Linant, 1834 (Deshayes, 1834). Fig. 107 C. (Synonym: *Vexillum moana* J. Cate, 1963, in part.) Length, 15 mm; diameter, 7 mm; aperture length, 5 mm. *Shell:* fusiform, turriculate; with strong axial ribs and weakly beaded spiral cords; red-brown spirally banded with white. *Spire:* protoconch of two smooth whorls; teleoconch of six to nine convex whorls separated by a distinct suture. *Sculpture:* broad, angulate axial ribs crossed by prominent coarse, spiral cords. *Aperture:* narrow, shorter than spire; lirate within; columella with about four folds. *Color:* dark red-brown, the base and a broad zone at the suture white; aperture with a broad brown zone.

These costellarids are very rare, dredged at depths of from 60 to 100 m.

V. leucozonias is widely distributed throughout the Indo-West Pacific from the Red Sea to the Philippines, Okinawa, and Tahiti. It is apparently rare throughout its range.

Vexillum (Costellaria) macrospirum (A. Adams, 1853a). Fig. 108 L. Length, 27 mm; diameter, 8 mm; aperture length, 12.5 mm. *Shell:* fusiform-slender; with fine axial ribs beaded by fine spiral threads; cream splashed with brown and with a white band on the periphery of the last whorl. *Spire:* protoconch of two conical whorls; teleoconch of 10 barely inflated whorls; suture deeply impressed. *Sculpture:* fine axial ribs, about 22 on the last whorl, the interspaces wider than the ribs and microscopically spirally striate; ribs crossed by spiral cords of about the same diameter, the junctions of ribs and cords forming nodular beads. *Aperture:* narrow; shorter than the spire; lirate within; columella with five folds. *Color:* cream splashed with brown in axially oriented blotches below the suture; last whorl with a broad white spiral band.

These costellarids are rare, found at depths of more than 100 m.

V. macrospirum was described from an unknown locale but appears to be widespread in the Pacific. The shells are distinguished from those of *V. bellum* by their more slender outline, closely spaced axial ribs, and the punctate effect of the spiral cords.

Vexillum (Costellaria) micra (Pilsbry, 1921). Fig. 107 D. (Synonym: *Mitra elima* Dall MS, J. Cate, 1963.) Length, 6.5 mm; diameter, 2.5 mm; aperture length, 3 mm. *Shell:* fusiform; with axial ribs and low spiral cords; dark brown. *Spire:* protoconch of about four rather flat-sided whorls; teleoconch of five to seven slightly convex whorls separated by a distinct, deep suture. *Sculpture:* numerous narrow, smooth axial ribs; interspaces of greater diameter than the ribs and crossed by low, spiral cords. *Aperture:* narrow, outer lip smooth; lirate within; columella with about four folds. *Color:* variable — dark brown, brown with lighter spirals at the periphery and base, cream with brown spirals. Beachworn shells are often russet brown.

These costellarids are common, found in sand and coral rubble at depths of from 20 to 100 m.

V. micra was described from the Hawaiian Islands. Although Cernohorsky (1970b) includes *V. micra* in the synonymy of *V. (Pusia) emiliae* (Garrett, 1880), the two species are clearly distinct, and both species are found in Hawaiian waters.

Vexillum (Costellaria) modestum (Reeve, 1845). Fig. 108 H. (Synonyms: *Vexillum comptum* A. Adams, Pilsbry, 1921; *Mitra farda* Dall MS, J. Cate, 1963.) Length, 15 mm; diameter, 5 mm; aperture length, 7 mm. *Shell:* fusiform, turreted; with axial ribs crossed by coarse spiral cords; white. *Spire:* protoconch of three and one-half straight-sided, conical, pink whorls; teleoconch of about seven convex whorls separated by a deep suture. *Sculpture:* prominent, coarse axial ribs crossed by spiral cords. *Aperture:* narrow; shorter than spire; lirate within; columella with about four folds. *Color:* white, apex and base pale pink and generally with an over-all pinkish cast; some shells may have a spiral of dark brown spots on the last whorl.

V. modestum is uncommon, occurring at depths of from 30 to 80 m.

This mitrid ranges throughout the Indo-West Pacific from Mauritius to the Philippines, Micronesia (Guam and the Marshall Islands), and Polynesia.

Vexillum (Costellaria) pacificum (Reeve, 1845). Fig. 108 I. (Synonyms: *Mitra wisemani* Dohrn, 1860; *M. exasperata* (Gmelin), Tinker, 1952.) Length, 15 mm; diameter, 6.5 mm; aperture length, 7.5 mm. *Shell:* fusiform, turreted; with keeled axial ribs shouldered below the suture and crossed by fine spiral striae; gray or white. *Spire:* attenuate, whorls angled at the suture; suture deep. *Sculpture:* prominent, sharply keeled axial ribs of irregular size crossed by spiral threads which render the ribs nodulose at the points of intersection. *Aperture:* about equal in length or shorter than the spire; with beaded lirae; columella with four or five folds. *Color:* white to cream, usually with an interrupted brown spiral on the last whorl.

These costellarids are very common at depths of from 30 to 80 m.

V. pacificum ranges through the Indo-West Pacific from Mozambique and Mauritius to the Philippines, Ryukyu Islands, Micronesia (Marshall Islands), and Polynesia.

Vexillum (Costellaria) radix (Sowerby, 1874). Fig. 108 E. Length, 17 mm; diameter, 5 mm; aperture length, 7 mm. *Shell:* fusiform, slender; with curved, angulate axial ribs and spiral grooves in the interspaces; light brown spirally banded with cream on the last whorl. *Spire:* protoconch of two glassy, conical whorls; teleoconch of seven or eight slightly convex whorls, barely angulate at the suture; suture impressed. *Sculpture:* elevated, angulate, curved axial ribs, the interspaces slightly wider than the ribs and crossed by fine spiral grooves which barely extend to the summits of the ribs. *Aperture:* narrow; shorter than the spire; contracted basally; outer lip thin; lirate within; columella with four or five folds. *Color:* fawn or light brown, with a broad, light spiral band on the periphery of the last whorl and on the apical whorls.

These costellarids are uncommon, dredged at depths of 100 to 200 m.

V. radix is known in the Pacific from Fiji where it is uncommon, in deep water (Cernohorsky, 1965).

Vexillum (Costellaria) sp. cf. *rufofilosum* (E. A. Smith, 1876). Fig. 108 D. Length, 10 mm; diameter, 3.5 mm; aperture length, 3.7 mm. *Shell:* elongate-cylindrical; with strong axial ribs cut by punctured grooves and flat spiral cords; white banded with brown. *Spire:* protoconch of three and one-half smooth, conical whorls; teleoconch of seven slightly convex whorls angulate at the deeply impressed suture. *Sculpture:* bold, angulate, elevated, curved axial ribs (14 or 15 on the last whorl), the ribs cut by a shallow subsutural groove; interspaces of slightly greater diameter than the ribs; spiral sculpture of flat cords; axial ribs granulose at the base. *Aperture:* shorter than spire; narrow; outer lip faintly crenulate; lirate within; columella with four folds; siphonal canal longer than aperture. *Color:* white, spirally banded with brown on the periphery of the last whorl.

These costellarids are uncommon, found at depths of 100 to 400 m.

V. (C.) rufofilosum was described from San Cristobal, Solomon Islands, and is included in the synonymy of *V. (C.) daedalum* (Reeve, 1845) from the Philippines by Cernohorsky (1976a). The Solomon Island shells seem far more similar to the Hawaiian shells than do the Philippine shells, which are biconic and inflated, with very strong sculpture, and reference is, therefore, made to the Smith species rather than that of Reeve (1845).

Vexillum (Costellaria) unifasciatum (Wood, 1828). Fig. 108 J. Length, 28 mm; diameter, 11 mm; aperture length, 12 mm. *Shell:* fusiform, turreted, solid; with axial ribs angulated at the suture and spirally corded interspaces; white with a spiral band of dark brown. *Spire:* protoconch of three and one-half smooth, conical white whorls; teleoconch of seven or eight turreted whorls; suture deep. *Sculpture:* bold axial ribs which are slightly nodular at the shoulders of the whorls; interspaces of greater diameter with spiral cords and deep grooves. *Aperture:* straight, narrow; shorter than spire; lirate within; outer lip thin, crimped; columella with four folds. *Color:* white spirally banded with red or dark brown around the periphery of the last whorl and at the suture of the earlier whorls.

This species occurs at depths of from 15 to 20 m. Shells are uncommon.

V. unifasciatum occurs throughout the Pacific from the Philippines to Micronesia and Polynesia.

Vexillum (Costellaria) wolfei Cernohorsky, 1978a. Fig. 108 C. Length, 7 mm; diameter, 2.5 mm; aperture length, 3 mm. *Shell:* ovate-fusiform; turreted; with crisp axial ribs and coarsely spirally striate interspaces; cream spirally banded with brown. *Spire:* protoconch of three smooth, glistening, conical whorls; teleoconch of five angulate, inflated whorls; suture distinctly ledged. *Sculpture:* crisp, angulate axial ribs, about 13 on the last whorl, interspaces of about the same diameter as the ribs and with coarse spiral cords which do not cross the ribs except for a single subsutural groove which produces a beaded effect at the suture. *Aperture:* wide; less than half the length of the spire; lirate within; columella with three or four folds. *Color:* cream lightly spirally banded with brown below the suture and around the base of the last whorl.

These costellarids are common at depths of from 50 to 100 m.

V. wolfei was described from the Hawaiian Islands. The shells are distinguished from those of *V. (C.) amanda* (Reeve, 1845), described from the Philippines, by their smaller size (the types of *V. (C.) amanda* are about 15 mm in length), less solid texture, more glossy surface, and the more slender sutural nodules (Cernohorsky, 1978a). If the shells of *V. (C.) wolfei* are compared with those of *V. (C.) malcomensis* Melvill and Standen, 1901, from the Persian Gulf, which Cernohorsky (1976a) includes in the synonymy of *V. (C.) amanda*, some of the differences with *V. (C.) amanda* disappear. The shells of *V. (C.) malcomensis* are small, about 9 mm in length, and the sculpture is finer and more regular than in shells of *V. (C.) amanda* from shallow water. The Persian Gulf shells were dredged from depths similar to those at which *V. (C.) wolfei* is found; *V. (C.) wolfei* may, therefore, be a synonym of *V. (C.) malcomensis*, but this determination awaits critical scanning electron microscope studies of the protoconch and radulae of costellarids from both areas.

Vexillum (Costellaria) xenium (Pilsbry, 1921). Fig. 108 G. (Synonym: *Mitra agria* Dall MS, J. Cate, 1963.) Length, 26 mm; diameter, 10 mm; aperture length 11.5 mm. *Shell:* fusiform-ovate; with numerous small axial ribs and spiral grooves; white spirally banded with brown on the last whorl. *Spire:* protoconch of at least two dark purple, conical whorls; teleoconch of nine inflated whorls; suture distinct, ledged. *Sculpture:* axial sculpture of narrow, slightly sinuous axial ribs, 22 on the last whorl, the interspaces of about the same diameter as the ribs; interspaces cut by spiral grooves which do not cross the ribs; base with two or three beaded cords. *Aperture:* narrowly ovate, shorter than spire; outer lip thin; lirate within; columella with three or four sharp folds. *Color:* white, spirally banded with a broad brown band on the last whorl and with narrow spirals of brown on each of the apical whorls, splashes of dark brown below the suture; apical two or three whorls dark brown.

These costellarids are uncommon, found at depths of 30 to 100 m.

V. xenium was described from the Hawaiian Islands. The shells are distinguished from those of *V. (Pusia) approximatum* by their smaller and more numerous ribs, brown banding, and dark protoconch.

Vexillum (Pusia) approximatum (Pease, 1860). Fig. 109 A. Length, 17 mm; diameter, 8 mm; aperture length, 10 mm. *Shell:* fusiform-ovate; labrum lirate; with axial ribs separated by spiral cords; white sometimes flecked with brown. *Spire:* protoconch of three and one-half conical, golden brown whorls; projecting, attenuate; last whorl obese; suture deep and distinct. *Sculpture:* prominent axial ribs on all whorls and deep spiral grooves which give rise to flat spiral cords in the interspaces. *Aperture:* about equal in height or shorter than spire; outer lip crimped; labrum lirate; columella with four or five folds. *Color:* white, sparsely flecked with brown, last whorl with a brown band about the periphery.

Specimens have been dredged at depths of more than 30 m and shells are also known from subfossil material dredged from Honolulu Harbor, Oahu and beach drift in the Leeward Islands.

V. approximatum appears to be restricted in its distribution to Polynesia and the Hawaiian Islands.

Vexillum (Pusia) cancellarioides (Anton, 1839). Fig. 109 B. (Synonym: *Mitra nodosa* Swainson, 1823, Martens and Langkavel, 1871.) Length, 16 mm; diameter, 10 mm; aperture length, 10 mm. *Shell:* fusiform-ovate, solid; labrum lirate; with sharply nodulose axial ribs and fine spiral striae; white. *Spire:* moderately short; whorls turreted; last whorl inflated; suture channeled. *Sculpture:* spiral rows of nodules and finely spirally striate interspaces. *Aperture:* wide; longer than spire; outer lip thin; lirate within; columella with three folds, the apical the largest. *Color:* creamy white; aperture yellow and interior dark brown; juvenile shells may have a brown peripheral band.

These costellarids are common, found in the habitat of *Drupa ricina* and *Morula granulata* on surf-splashed boulders in the intertidal zone. Egg capsules were produced by a female in an aquarium in September, 1973. The capsules were transparent, about 3 mm in diameter, and each contained about 140 veliger larvae (Purtyman, 1974).

This species is widely distributed in the Indo-West Pacific, ranging from the Seychelles Islands to southern Japan, Micronesia (Mariana and Marshall Islands), and Polynesia (Fiji, Tonga, Cook, and Line Islands).

Vexillum (Pusia) capricornea (Hedley, 1907). Fig. 110 D. (Synonym: *Vexillum (Pusia) salisburyi* Cernohorsky, 1976b.) Length, 5.5 mm; diameter, 2.5 mm; aperture length, 2 mm. *Shell:* ovate; stout; with thick axial ribs and spirally striate interspaces; rose red. *Spire:* protoconch of one and one-half inflated whorls; teleoconch of five moderately convex whorls; suture distinct, rather deep but not channeled. *Sculpture:* axial sculpture of stout, rounded, smooth axial ribs, 14 on the last whorl; interspaces of slightly lesser than the ribs with spiral sculpture of fine threads. *Aperture:* narrow; shorter than spire; columella with four folds; outer lip simple with fine internal lirations. *Color:* rose red.

These costellarids are found at depths of more than 10 m. Beachworn shells are common in beach drift and may be yellow-brown or orange.

V. capricornea was described from Sydney, Australia; Cernohorsky's *V. salisburyi* was described from Hawaii. The species also occurs in the Ryukyu Islands.

Vexillum (Pusia) catenatum (Broderip, 1836). Fig. 110 A. Length, 13 mm; diameter, 5 mm; aperture length, 7 mm. *Shell:* biconic, inflated; with bold axial ribs; glossy, cream with a single spiral of brown spots below the suture. *Spire:* teleoconch of five inflated whorls; whorls slightly angulate at the impressed suture. *Sculpture:* bold axial ribs, about 30 on the last whorl, the interspaces about the same diameter as the ribs and grooved by fine spiral striae which do not cross the ribs except below the suture. *Aperture:* narrow, less than half the length of the spire; lirate within; columella with three or four folds, the two apical folds especially prominent; base with three granular spirals; outer lip with a prominent parietal denticle. *Color:* glossy, cream with a single spiral of brown spots in the interspaces between the ribs below the suture.

These costellarids are rare, known only from subfossil shells from depths of about 30 m and from Pleistocene fossil beds.

V. catenatum was described from Anaa Island, and occurs throughout the Indo-West Pacific. The shells apparently vary in size, shape, and color pattern. Broderip's types (in the British Museum (Natural History)) are slender, fusiform shells (length,

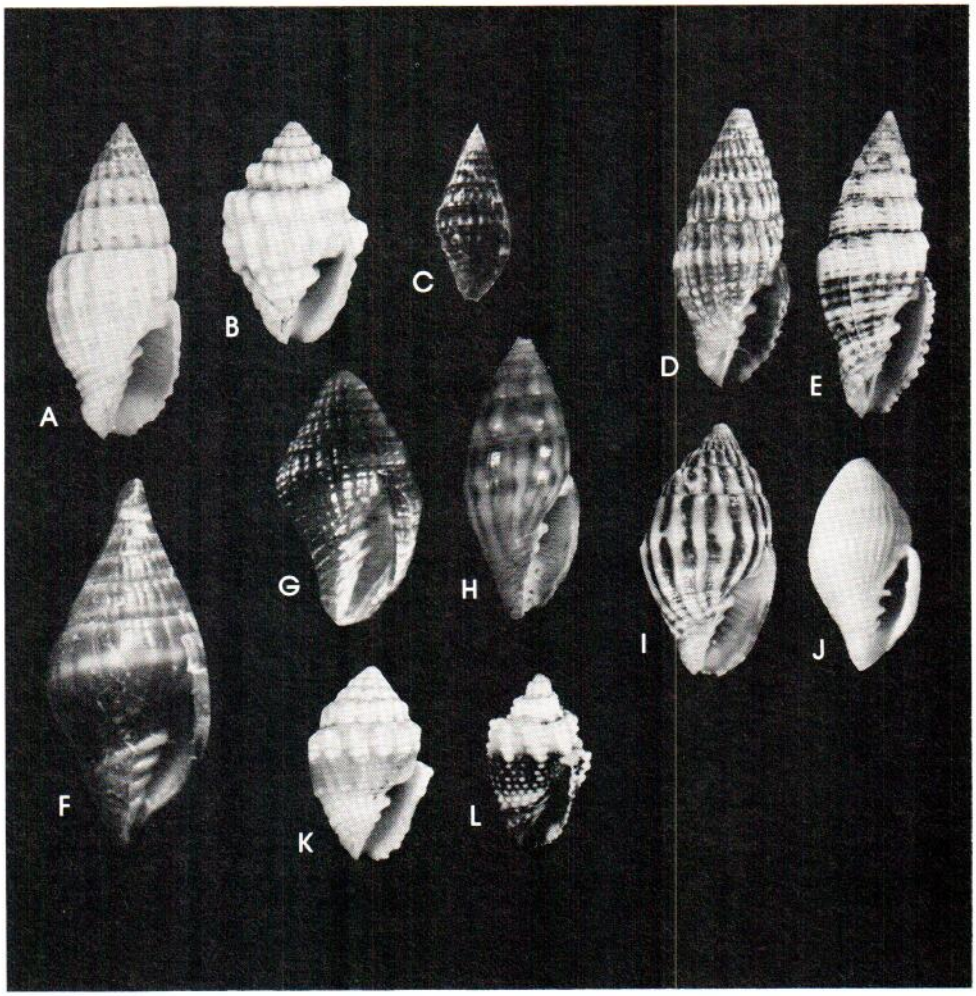


Figure 109.—**Costellariidae.** A. *Vexillum (Pusia) approximatum*, length 17 mm. B. *V. (P.) cancellarioides*, length 16 mm. C. *V. (P.) microzonias*, length 15 mm. D. *V. (P.) unifascialis*, length 15 mm. E. *V. (P.) cumingii*, length 17 mm. F. *V. (P.) emiliae*, length 10 mm. G. *V. (P.) piceum*, length 9 mm. H. *V. (P.) moelleri*, length 19 mm. I. *V. (P.) lautum*, length 14 mm. J. *V. (P.) turben*, length 25 mm. K. *V. (P.) patriarchalis*, length 12 mm. L. *V. (P.) tuberosum*, length 15 mm.

13 mm; diameter, 5 mm), with the siphonal canal elongate and recurved, the axial ribs almost obsolete and with little or no spiral sculpture, and cream with large, prominant chestnut spots. Cernohorsky (1970b) includes in the synonymy of *V. (P.) catenatum* such diverse forms as the shells of *V. (P.) smithii* (Sowerby, 1890) and *V. (P.) recurvirostris* (Sowerby, 1908c), both from Mauritius. The shells of the former are obese, with prominent ribs, and cream without noticeable spotting. The shells of the latter are also inflated, sculptured with widely spaced axial ribs and there is a golden yellow, beaded subsutural band. The Hawaiian shells resemble those of *V. (P.) smithii*.

Vexillum (Pusia) cumingii (Reeve, 1844). Fig. 109 E. Length, 25 mm; diameter, 11 mm; aperture length, 13 mm. *Shell:* fusiform-ovate; whorls angulate at the suture; with axial ribs and coarse spiral threads; yellow to orange-brown blotched with white. *Spire:* protoconch not known; teleoconch of seven or eight slightly inflated whorls which are angulate at the suture; suture impressed. *Sculpture:* bold, angulate axial ribs, about 15 on the last whorl; interspaces of slightly greater diameter crossed by coarse spiral cords. *Aperture:* narrow; about equal in height to the spire; outer lip crimped; lirate within; columella with about four folds. *Color:* yellow to dark orange-brown, variegated with large, irregular white zones and dark brown spiral threads.

These costellarids are uncommon, found at depths of 8 to 24 m.

V. cumingii was described from the Philippines and is found throughout the Pacific from the Philippines to Polynesia and Hawaii.

Vexillum (Pusia) emiliae (Garrett, 1880). Fig. 109 F. Length, 10 mm; diameter, 4.5 mm; aperture length, 4.5 mm. *Shell:* ovate-biconic; with obsolete axial ribs; brown spirally banded with white on the last whorl. *Spire:* protoconch of four and one-half conical brown whorls; teleoconch of about four convex whorls; suture deep. *Sculpture:* elevated axial ribs which are more keeled on the apical whorls than on the abapical whorls where they become obsolete; ribs and interspaces of about equal diameter, interspaces smooth; ribs cut into nodules by a spiral groove below the suture. *Aperture:* narrow; outer lip thin; labrum lirate; columella with four strong, oblique folds; base with spiral threads and cords. *Color:* dark brown, with a narrow spiral band of white on the periphery of the last whorl and below the suture on the other whorls.

These costellarids are rare, found at depths of about 10 m.

V. emiliae was described from the Tuamotu Islands (as *Turricula plicatula* Pease, 1868a).

Vexillum (Pusia) infaustum (Reeve, 1845). Fig. 110 F. Length, 9.2 mm; diameter, 3.9 mm; aperture length, 5.1 mm. *Shell:* ovate to elongate-ovate; with axial ribs and deep spiral grooves which bisect the axial ribs; cream with red-brown spots on the axial ribs. *Spire:* protoconch of two to two and one-half white whorls; teleoconch of seven or eight convex whorls which are angulate at the suture; suture deeply impressed. *Sculpture:* close-set, elevated, angulate axial ribs, the interspaces of lesser diameter than the ribs and decussated by deep spiral grooves which bisect the axial ribs. *Aperture:* equal in height to the spire; outer lip thin or obsoletely crenulate; columella with three or four oblique folds; anterior canal spirally corded. *Color:* cream to light yellow, with small red-brown spots or short spiral lines on the summits of the axial ribs.

These costellarids are rare, found in sand at depths of 20 to 100 m.

V. infaustum was described from the Philippine Islands and is also known from Fiji.

Vexillum (Pusia) lautum (Reeve, 1845). Figs. 106 B; 109 I. (Synonyms: *Mitra consanguinea* Reeve, Mant, 1923; *Mitra adamsi* Dohrn, 1862.) Length, 14 mm; diameter, 8 mm; aperture length, 9 mm. *Shell:* fusiform-ovate; axially ribbed with convex arches and with spirally striate interspaces; ribs brown, interspaces almost

black. *Spire:* protoconch of three and one-half conical, smooth, dark brown whorls; last whorl of teleoconch somewhat obese; suture impressed. *Sculpture:* prominent, arched axial ribs; interspaces of greater diameter and with spiral striae. *Aperture:* narrow; longer than spire; outer lip smooth; labrum lirate; columella with about four folds. *Color:* axial ribs brown, gray or white, interspaces almost black with a tinge of orange, and with a white peripheral band of nebulous white spots.

V. lautum is one of the commonest shallow-water costellarids, found under rocks in tide pools and shoreward of fringing reefs. Four-lobed veliger larvae are found in the plankton from September through November; they metamorphose when three whorls are complete, at 870 μm in length (J. B. Taylor, 1975).

V. lautum is widely distributed throughout the Pacific, from the Philippines to southern Japan, New Caledonia, Micronesia (Marshall Islands) and Polynesia.

Vexillum (Pusia) lenhilli Kay, new species. Fig. 110 G. Length, 6.25 mm; diameter, 2.5 mm; aperture length, 3 mm (holotype). Mean length of 31 shells, 5.1 mm, range 3.5 to 7.0 mm. *Shell:* fusiform-ovate; with angulate axial ribs and spiral cords; orange-red spirally banded with white and with a brown spiral thread around the periphery of the last whorl. *Spire:* protoconch of three and one-half smooth, conical, pink whorls; teleoconch of six inflated whorls, angled at the suture; suture deep, ledged. *Sculpture:* straight, slightly angulate axial ribs, about 14 on the last whorl, the interspaces the same diameter as the ribs, shallow and crossed by flat spiral cords, about 10 on the last whorl; base with four granular cords. *Aperture:* wide; about half the length of the spire; outer lip sinuous, thickened centrally within; lirate within; with a prominent parietal nodule; columella with four oblique folds, the apical folds most prominent. *Color:* orange-red with a brown spiral thread at the suture, banded around the periphery of the last whorl with a continuous or interrupted thread of dark brown, and spirally banded with white between the brown threads. Juvenile shells orange-yellow with a spiral thread of brown around the periphery of the last whorl and below the suture on the other whorls.

These costellarids are common at depths of about 60 m.

Type locality: Kepuhi Point, Oahu, from a depth of 60 m in sand and rubble. *Holotype:* B. P. Bishop Museum No. 9810. *Paratypes:* Australian Museum; British Museum (Natural History); R. Salisbury collection; U. S. National Museum.

These colorful, small costellarids are distinguished from other members of the subgenus which have threadlike dark spirals as part of the color pattern, such as *V. (P.) suavis,* by the turriculate form and orange red color. In sculpture the shells are similar to those of *V. (Costellaria) xenium* but are much smaller and the sculpture is finer. This species is named for Mr. Len Hill who participated in many of the dredging activities which led to the discovery of this species.

Vexillum (Pusia) microzonias (Lamarck, 1811). Fig. 109 C. (Synonym: *Vexillum dermestina* (Lamarck), Pilsbry, 1921.) Length, 10 mm; diameter, 5 mm; aperture length, 6 mm. *Shell:* elongate-ovate, solid; with blunt, angulate axial ribs and fine spiral striae; brown spirally banded with white. *Spire:* protoconch of two conical, white whorls; teleoconch of seven to nine convex whorls; suture impressed. *Sculpture:* blunt to angulate axial ribs sometimes obsolete on the back, the interspaces about the same diameter as the ribs and spirally striate, the striae occasionally overriding the

ribs. *Aperture:* equal in height or longer than the spire; outer lip lirate and moderately thick; columella with four or five prominent folds; base with three to eight nodulose spiral cords. *Color:* dark brown to red-brown, with a narrow spiral band of white adjoining the suture on the apical whorls and on the periphery of the last whorl, aperture white.

These costellarids are rarely found, occurring at depths of 100 m.

V. microzonias was described from the Indian Ocean and is widely distributed in the Indo-West Pacific.

Vexillum (Pusia) moelleri (Kuster, 1840). Fig. 109 H. (Synonyms: *Turricula flammulata* Pease, 1868b; *Mitra baldwinii* Melvill, 1899.) Length, 19 mm; diameter, 9 mm; aperture length, 12 mm. *Shell:* obovate; smooth; glossy dark gray with gray-brown flammules. *Spire:* apex projecting; suture impressed. *Sculpture:* apical whorls with numerous, fine axial ribs and fine spiral striae in the interspaces; last whorl generally smooth. *Aperture:* wide; shorter than aperture; outer lip flaring; labrum lirate; columella with four or five folds. *Color:* lead-gray with black-brown flamelike axial streaks. Beachworn shells are creamy yellow streaked with brown.

V. moelleri is known in the Hawaiian Islands only from beachworn and subfossil shells from dredge spoils.

This species appears to be limited in its distribution to the Pacific and has been recorded from the Philippines, Micronesia (Marshall Islands), and Polynesia.

Vexillum (Pusia) oryzum Kay, new species. Fig. 110 H. Length, 5 mm; diameter, 2 mm; aperture length, 2.5 mm (holotype). *Shell:* ovate; with fine axial ribs and recessed spiral threads; cream. *Spire:* protoconch of three smooth, conical, white whorls; teleoconch of four inflated whorls; suture impressed, barely ledged. *Sculpture:* fine, rounded axial ribs, about 23 on the last whorl, the interspaces of slightly greater diameter, shallow, laced with recessed spiral threads producing a punctate effect. *Aperture:* wide; about one half the length of the spire; outer lip thin; strongly lirate within; columella with four oblique folds; siphonal canal abruptly short, straight. *Color:* cream shadowed with gray-white on the periphery of the last whorl.

These costellarids are extremely rare and the two specimens known were dredged from depths of 66 and 200 m respectively.

Type locality: Kepuhi, Oahu, in sand and coral rubble at the base of a cliff, depth of 66 m. *Holotype:* B. P. Bishop Museum No. 9830. *Paratype:* B. P. Bishop Museum.

In size and shape these costellarids are not unlike the shells of *V. (P.) blanfordi* (Melvill and Standen, 1901), from the Gulf of Oman and *V. (P.) bipartita* (Smith, 1884) from the Mascarene Islands. The shells of *V. (P.) blanfordi* are distinctly mottled with brown, however, and the ribs are somewhat obsolete, while the shells of *V. (P.) bipartita* are fusiform rather than ovate and, they, too, are banded with brown.

Vexillum (Pusia) patriarchalis (Gmelin, 1791). Fig. 109 K. (Synonym: *Mitra depressa* Dall MS, J. Cate, 1963.) Length, 12 mm; diameter, 9 mm; aperture length, 9 mm. *Shell:* obovate-depressed; with angulate axial ribs, fine axial threads and sharply

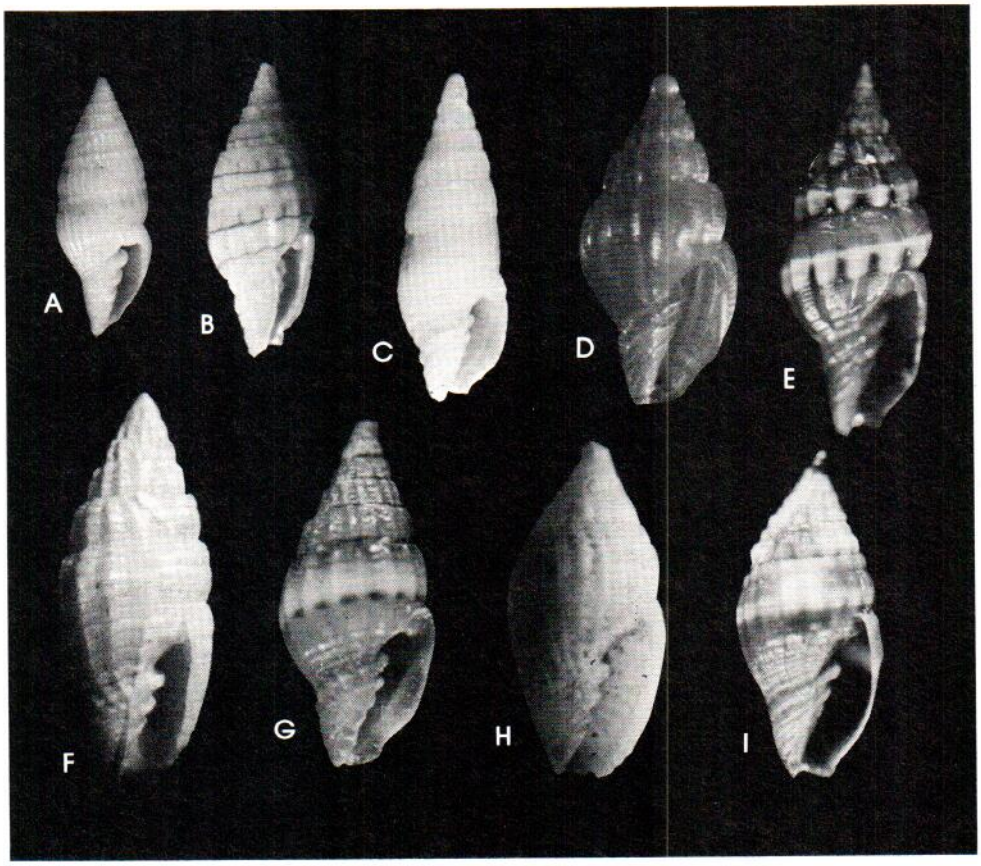


Figure 110.—**Costellariidae.** A. *Vexillum (Pusia) catenatum*, length 8 mm. B. *V. (P.) suavis*, length 7 mm. C. *V. (Costellaria) cosmani*, length 8 mm (holotype). D. *V. (Pusia) capricornea*, length 6 mm. E. *V. (P.) rubrum*, length 7 mm. F. *V. (P.) infaustum*, length 9 mm. G. *V. (P.) lenhilli*, length 6.25 mm (holotype). H. *V. (P.) oryzum*, length 5 mm (holotype). I. *V. (P.) tusum*, length 10 mm.

coronate suture; last whorl red-brown, apical whorls white. *Spire:* whorls turreted and angulate; suture channeled. *Sculpture:* broad, angulate axial ribs becoming coronate and spinose at the suture but obsolete on the ultimate half of the last whorl; additional sculpture of deep, fine spiral striae and nodulose cords at the base. *Aperture:* longer than spire; labrum lirate; columella with about four folds. *Color:* dark red-brown; apex, sutural coronations and basal spiral cords white; aperture brown.

V. patriarchalis is rather rare in the Hawaiian Islands; occasional specimens have been dredged at depths of 60 m. Beachworn shells are not uncommon in drift along the northern shores of the Islands.

This species is widely distributed in the Indo-West Pacific, ranging from the Seychelles to the Philippines, southern Japan, Okinawa, Micronesia (Marshall Islands), and Polynesia.

The shells of *V. patriarchalis* are distinguished from those of *V. tuberosum* (Reeve, 1845) by their depressed shape, spinose and angulate ribs, and deep spiral grooves.

Vexillum (Pusia) piceum (Pease, 1860). Fig. 109 G. (Synonyms: *Mitra millecostatum* Broderip, J. Cate, 1963; *M. lipara* Dall MS, J. Cate, 1963.) Length, 9 mm; diameter, 4 mm; aperture length, 6 mm. *Shell:* fusiform-ovate; with fine axial ribs cancellated by spiral threads; labrum lirate; dark brown. *Spire:* protoconch of five conical, smooth, red-brown whorls; apex attenuate, teleoconch of six and one-half moderately convex whorls; suture impressed. *Sculpture:* numerous, broad, flat axial ribs cancellated by spiral grooves, the grooves separating the ribs into small squares. *Aperture:* narrow, longer than spire; labrum lirate; columella with four folds. *Color:* black-brown with a narrow, pale subsutural spiral line; occasional shells with one or two small, square blotches between the subsutural line and the suture.

These costellarids are found under rocks and rubble at depths of from 3.5 to 6.5 m; worn shells are common in beach drift.

This species occurs in the Pacific and has been recorded from Tonga, the Society Islands, the Tuamotus, and the Line Islands.

Vexillum (Pusia) rubrum (Broderip, 1836). Fig. 110 E. Length, 7 mm; diameter, 3 mm; aperture length, 3 mm. *Shell:* fusiform-ovate; with prominent axial ribs and fine spiral striae; labrum lirate; rosy-pink with a narrow spiral of white and a wider band of darker pink. *Spire:* protoconch of four attenuate, conical, smooth, pink whorls; teleoconch with about eight inflated, convex whorls; suture distinct but shallow. *Sculpture:* prominent, bold axial ribs, the interspaces of greater diameter and spirally striate. *Aperture:* narrow; outer lip smooth; labrum lirate; columella with about four folds. *Color:* rosy-pink, last whorl with a narrow white spiral and a broad band of darker rosy-red toward the base; interstices next to the white line may be darker.

These costellarids occur at depths of about 20 m, usually in coral heads, and to 60 m.

V. rubrum is distributed throughout the Indo-West Pacific from Mauritius to the Marshall Islands and Polynesia.

Vexillum (Pusia) suavis (Souverbie, 1875). Fig. 110 B. (Synonym: *Mitra mitata* Dall MS, J. Cate, 1963.) Length, 7 mm; diameter, 4 mm; aperture length, 4 mm. *Shell:* biconic; with nodulose axial ribs; rose pink with a white spiral band bordered in brown. *Spire:* attenuate; whorls angulate and nodulose at the impressed suture. *Sculpture:* large, close-set axial ribs which are nodulose at the suture; interspaces of about the same diameter as the ribs and spirally striate. *Aperture:* narrow, sinuous; labrum lirate; columella with four folds. *Color:* rosy pink, last whorl with a white spiral band bordered by narrower brown spirals which axially radiate darker brown streaks.

These costellarids are rarely found, known from shells found in the dredger dump at Kewalo Basin, Oahu.

V. suavis was described from New Calendonia and is distributed through the Pacific from the Philippines to Polynesia.

Vexillum (Pusia) tuberosum (Reeve, 1845). Fig. 109 L. (Synonym: *Mitra patriarchalis* Lamarck, Tinker, 1952.) Length, 15 mm; diameter, 8 mm; aperture length, 9 mm. *Shell:* obovate; with coarse axial ribs and coronate suture; dark brown spirally

banded with white. *Spire:* teleoconch of five short whorls; suture coronate. *Sculpture:* coarse axial ribs that are bluntly coronate at the suture and prominent flat spiral cords; interspaces of cords finely spirally striate. *Aperture:* narrow; outer lip thick; labrum lirate; columella with about four folds. *Color:* dark brown with a broad spiral band of white at the suture; aperture brown.

These costellarids have been dredged at depths of from 10 to 90 m off Oahu, and occur on reefs off Maui and in tide pools on Hawaii. They are uncommon. Although most species of *Pusia* are crack and crevice dwellers, *V. tuberosum* occurs in sand in Hawaii.

V. tuberosum is widely distributed in the Indo-West Pacific, from East Africa to Micronesia (Marshall Islands) and Polynesia.

Vexillum (Pusia) turben (Reeve, 1844). Fig. 109 J. (Synonym: *Vexillum (Idiochila) turben kanaka* Pilsbry, 1921.) Length, 25 mm; diameter, 11 mm; aperture length, 15 mm. *Shell:* obesely pyriform; with numerous, close-set axial ribs; labrum lirate; dark orange. *Spire:* whorls inflated, convex; suture channeled. *Sculpture:* numerous, close-set, curved axial ribs, the interspaces of slightly greater diameter and finely, spirally striate. *Aperture:* narrow; longer than spire; outer lip thin; labrum lirate; columella with five or six folds. *Color:* uniformly dark orange; beachworn shells pale yellow.

Shells of *V. turben* are rare, known only from dredged subfossil shells.

This species is distributed throughout the Indo-West Pacific from Mauritius to the Philippines and Polynesia.

Vexillum (Pusia) tusum (Reeve, 1845). Figs. 106 C; 110 I. (Synonyms: *Mitra olgae* Dall MS, J. Cate, 1963; *M. propetusa* Dall MS, J. Cate, 1963; *M. stearnsiana* Dall MS, J. Cate, 1963; *Pusia alveolus* Reeve, J. Cate, 1963.) Length, 10 mm; diameter, 6 mm; aperture length, 6 mm. *Shell:* fusiform-obese; stout; with nodulose axial ribs and spirally corded; labrum lirate; dark brown with a peripheral white band. *Spire:* protoconch of four conical, smooth, dark brown whorls, apical whorl cream, others dark brown; whorls of teleoconch barely convex; suture channeled. *Sculpture:* numerous axial ribs, the interspaces of lesser diameter and with spiral cords which make the ribs nodulose at the intersections. *Aperture:* narrow; labrum lirate; longer than spire; columella with about four folds. *Color:* dark brown with a white spiral at the periphery of the last whorl.

These costellarids occur at depths of from 5 to 100 m; beachworn shells are common in drift. The four-lobed veliger larvae are most abundant in the plankton in August; they metamorphose when three to four whorls are complete, at a length of 960 μm (J. B. Taylor, 1975).

V. tusum is widely distributed in the Indo-West Pacific, from Mauritius to the Philippines, Micronesia (Marshall Islands), and Polynesia.

Vexillum (Pusia) unifascialis (Lamarck, 1811). Fig. 109 D. (Synonym: *Vexillum aureolatum* Swainson, Pilsbry, 1921.) Length, 15 mm; diameter, 6 mm; aperture length, 7 mm. *Shell:* fusiform-ovate, turreted; with axial ribs and spiral cords; yellow, orange or red-brown spirally lineated with cream. *Spire:* projecting; whorls turreted

and the last whorl convex; suture impressed. *Sculpture:* axial ribs which are nodulose at the suture, the interspaces with faint spiral cords. *Aperture:* about equal in length to the spire; moderately narrow, labrum lirate; outer lip crimped; columella with four or five folds. *Color:* variable — yellow, orange or red-brown spirally lineated with one to three narrow bands; nodules occasionally white.

These costellarids are uncommon at depths of 20 m. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

V. unifascialis ranges throughout the Indo-West Pacific from the Red Sea to the Philippines, Micronesia (Marshall Islands), and Polynesia.

Family **Volutomitridae**

The mitridlike shell, volutid type of radula, and other anatomical features associated with the alimentary canal and reproductive system distinguish these neogastropods as a distinct family (Cernohorsky, 1970b; Ponder, 1973). The shell is small to moderate in size (10 mm to 47 mm) and is characterized by columellar folds. An operculum may be present. All recent species have been found in moderately deep water, at depths of from 27 to 1900 m. A single species has been reported from the Hawaiian Islands.

Volutomitra pailoloana (J. Cate, 1963). Fig. 107 J. (Synonym: *Mitra languida* Dall MS, J. Cate, 1963.) Length, 30 mm; diameter, 11 mm; aperture length, 15 mm. *Shell:* fusiform, solid; with low axial ribs and spiral threads; straw or tan. *Spire:* approximately six whorls exclusive of the protoconch; suture distinct. *Sculpture:* low, rounded axial ribs which become obsolete on the last whorl and spiral threads encircling the whorls. *Aperture:* narrow, about equal in length to the spire; outer lip smooth; columella with three folds. *Color:* straw to tan; aperture white; periostracum buff.

A single subfossil shell has been dredged at a depth of 30 m; other shells were dredged by the *Albatross* at depths of 500 to 600 m.

This species was described from the Hawaiian Islands.

Superfamily CONACEA

(TOXOGLOSSA)

Four closely related families form this superfamily, the Turridae, Conidae, Terebridae, and Speightiidae (not represented in Hawaii). The older name, Toxoglossa, refers to the extraordinary toxic quality of the radula which in the most specialized members of the group is composed only of marginal teeth developed as slender barbs and fitted with a toxin gland.

Turrids and cones live both on hard substrates and in soft substrates; terebrids are sand-dwellers. In the Conidae and Turridae the head bears tentacles with prominent eyes, often situated near the tips of the tentacles; in the Terebridae the eyes and tentacles are reduced or lost.

Family **Turridae**

The monumental task of reviewing the Turridae has been undertaken by A.W. B. Powell (1966), who describes the family as a "complex, plastic, very successful group that occupies a full range of marine habitats, covering all geographic areas from the tropics to the polar regions, and from shallow waters to the ocean deeps." The turrids comprise not only the largest family group among marine prosobranchs, but one of the oldest, with a time range extending well back into the Cretaceous (Powell, 1969).

The turrids are versatile in habitat and habits, although they are seldom found in large numbers, as are cones and terebrids. They live in sand and on hard substrates. They are carnivores, but differences in the form of the radula and in the structure of the digestive system suggest that they have a variety of feeding habits: those forms with central, lateral, and marginal teeth like those of the mesogastropods may engulf their prey; others with the toxoglossate radula and a long proboscis may sting their prey. The sexes are separate, the zygotes deposited in lenticular egg capsules in which veliger larvae, often with elaborately sculptured protoconchs, develop, or from which directly developing forms may emerge.

Although there is no characteristic shape by which members of the Turridae can be easily recognized, one shell feature is common to all members of the family: a slit or a shallow or deep sinus on the outer lip, variously located between the suture and the periphery of the last whorl. Turrid shells range in size from about 1 mm to more than 160 mm in length (in Hawaii from 3 mm to 100 mm). In form they simulate the shells of buccinids, cones, miters, and fasciolarids, and several species have been moved from one family to another as the limits of the families have been defined. An additional difficulty in classification stems from the fact that species with apparently almost identical teleoconchs may have quite dissimilar protoconchs and radular teeth. Powell (1966) recognizes genera and subgenera on the basis of shell characters and protoconchs; McLean (1971) utilizes radular teeth in defining at least subfamily groups. Protoconch descriptions may be misleading in that the elaborate sculpture of premetamorphic protoconchs is often worn in adult shells and shells with apparently unicarinate protoconchs may in the premetamorphic state be elaborately sculptured, as is, for example, *Carinapex minutissima* (Fig. 114 C). Nevertheless, in the absence of other characters, the protoconch remains a useful guide to at least subfamily placement.

The distinguishing features of the subfamilies found in Hawaiian waters are:

(1) Turrinae: shells mostly about 20 mm in length, some longer; fusiform with the siphonal canal short (*Turridrupa*) to long (*Gemmula, Turris*); sculpture of spiral keels with variously developed beading; found in sand at depths of more than 10 m.

(2) Clavinae: shells mostly small, less than 15 mm in length; fusiform with the siphonal canal truncate; surface of shell usually smooth and glossy, sculpture of axial ribs often cut into large nodules; found in shallow water in tide pools and occasionally to depths of 50 m.

(3) Mitrolumninae: shells small, less than 10 mm in length; ovate-biconic; with axial and spiral sculpture of about equal strength; distinguished especially by the V-shaped notch on the columella; found in tide pools and to depths of 60 m.

(4) Mangeliinae: shells small, usually less than 10 mm in length; ovate-biconic to ovate-fusiform; sculpture predominantly spiral or clathrate; found in shallow water in tide pools and on fringing reefs, occasionally to depths of 50 m.

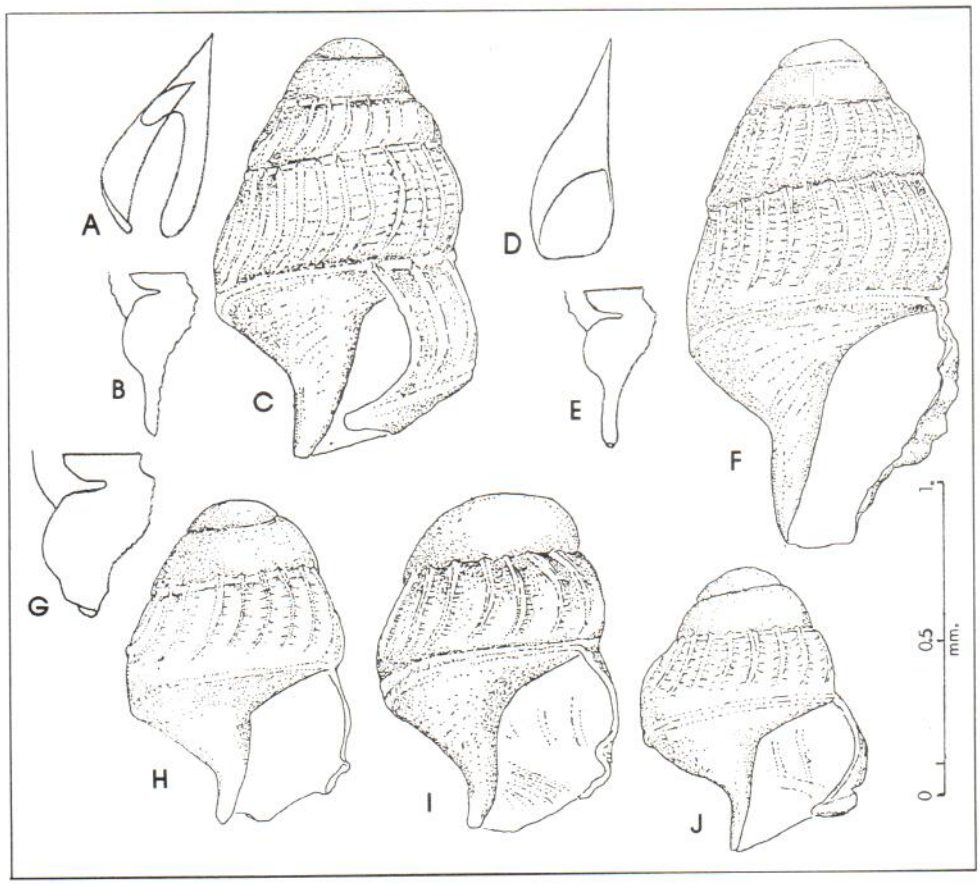


Figure 111.—**Turrinae.** A. Radular tooth, *Gemmula*. B. Profile, *Gemmula*. C. Premetamorphic protoconch, *Gemmula monilifera*. D. Radular tooth, *Xenoturris*. E. Profile, *Xenoturris*. F. Premetamorphic protoconch, *Xenoturris kingae*. G. Profile, *Turridrupa*. H. Premetamorphic protoconch, *Turridrupa bijubata*. I. Premetamorphic protoconch, *T. weaveri*. J. Premetamorphic protoconch, *T. albofasciata*. (A, D. from Powell, 1966; B, E, G, Powell, 1964; C, F, H, I, J from J. B. Taylor, 1975.)

(5) Daphnellinae: shells both small, less than 10 mm in length, and large, to 75 mm (*Spergo, Tritonoturris*); ovate to fusiform; with spiral keels, spiral and axial threads; found in shallow water (*Kermia*), at SCUBA depths of 15 to 20 m (*Tritonoturris*), and to depths of several hundred meters (*Spergo*).

Subfamily **Turrinae**

The shells of the Turrinae are fusiform with a long, straight siphonal canal (*Gemmula, Turris*) or a truncate canal (*Cryptogemma, Turridrupa, Xenoturris*). The sinus is deep, V-shaped, and near the peripheral keel. The operculum is leaf-shaped. The marginal teeth of the radula are either shaped like a wishbone or duplex (Fig. 112 D).

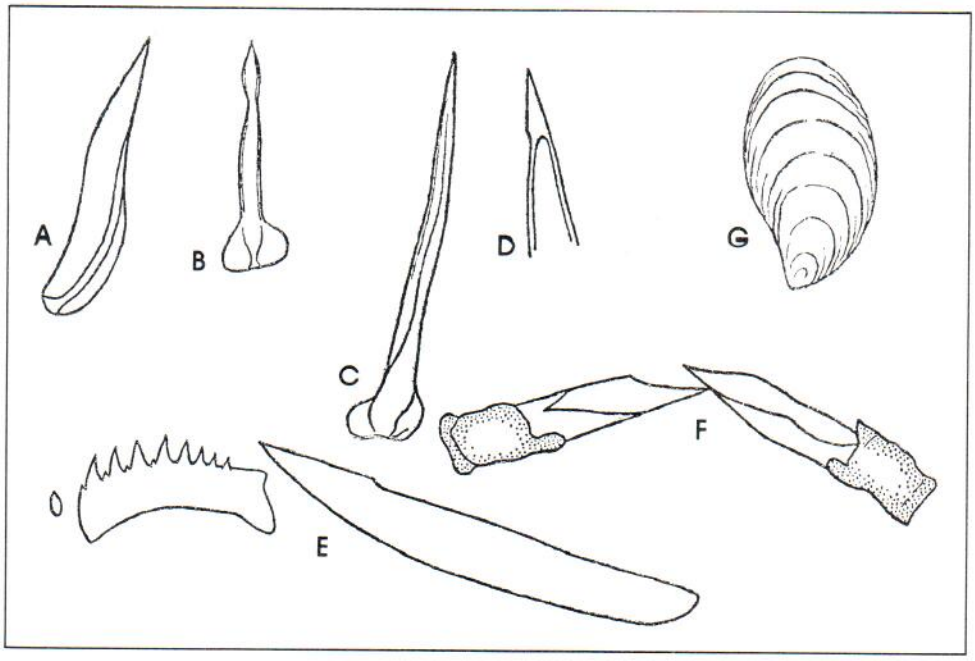


Figure 112.—Turrid radular teeth. A. *Carinapex minutissima*. B. *Mitromorpha* sp. C, D. *Lienardia mighelsi*. E. *Spergo glandiniformis*. F. *Clavus* sp. G. Operculum, *Carinapex minutissima*. (From Powell, 1966.)

Members of the Turrinae are found only subtidally in Hawaii, at depths of 10 m or more. They appear to be sand dwellers. The veliger larvae of five species were described from the plankton of Kaneohe Bay, Oahu; all were four-lobed veligers with large protoconchs (ca. 1 mm), with a smooth apical whorl and axial ribs on the succeeding whorls (Fig. 111) (J. B. Taylor, 1975).

Of the 15 species recorded here, 11 species or subspecies of *Turris* and *Xenoturris* are endemic; and three of the four species of *Turridrupa* and one species of *Gemmula* are found elsewhere in the Pacific. The Turrinae are not well represented on the oceanic islands of the Pacific and relatively few species occur east of the western Pacific arc (Powell, 1964). Only three species are found in the Marshall Islands, for example. The 15 species recorded in Hawaii therefore represent a unique turrinid fauna among the oceanic islands of the Pacific.

Gemmula congener unilineata Powell, 1967. Fig. 113 A. Length, 31 mm; diameter, 10 mm. *Shell:* broadly fusiform, anterior canal long, straight; with gemmate cords; ivory-white with dark red. *Spire:* more than half the length of the shell; protoconch of three narrowly conical whorls, the two apical whorls smooth, the abapical axially costate; teleoconch of eight whorls. *Sculpture:* subsutural fold massive, of three gemmate spirals, the middle the strongest; shoulder slope moderately wide with three gemmate subcords; peripheral carina low-set, strong, of two spiral cords studded with about 32 closely spaced, axially fused nodes; last whorl with a single smooth cord below the carina, anterior canal corded. *Aperture:* sinus moderately deep, V-shaped;

interior of outer lip finely lirate. *Color:* ivory-white, subsutural fold and interspaces between peripheral nodes red-brown; periostracum pale straw-colored.

These turrids have been dredged at depths of 200-600 m off Kauai, Oahu, and Molokai.

G. congener unilineata was described from the Hawaiian Islands. Other subspecies of *G. congener* range from East Africa to the Philippines and Japan (Powell, 1967).

Gemmula interpolata Powell, 1967. Fig. 113 B. Length, 25 mm; diameter, 9 mm. *Shell:* broadly fusiform, anterior canal long, almost straight; peripheral carina noded; ivory-white, internodes of peripheral carina red-brown. *Spire:* slightly less than half the length of the aperture and siphonal canal; protoconch narrowly conical, of three and one-half dark brown whorls, the apical whorls smooth, the abapical whorl axially costate; teleoconch of about eight whorls. *Sculpture:* subsutural fold prominent, narrow-crested, smooth; shoulder slope straight, descending with crisp, smooth spiral cords; peripheral carina low-set, of two cords noduled by axially fused nodes; last whorl with eight or nine smooth cords and finer threads in the interspaces below the carina. *Aperture:* sinus deep, U-shaped, apex the width of the peripheral keel. *Color:* ivory-white sparsely maculated with red-brown, internodes of peripheral carina red-brown; periostracum pale-straw.

These turrids have been dredged from depths of 40 meters to 710 m from Laysan to Molokai and Lanai.

G. interpolata was described from the Hawaiian Islands. Powell (1967) suggests that it is allied to *G. gilchristi* (Sowerby, 1902) of the Indian Ocean and Japan.

Gemmula microscelida (Dall, 1895). (Not figured.) Length, 20 mm; diameter, 9 mm. *Shell:* broadly fusiform, siphonal canal short and twisted; axial ribs produced as rounded nodules on a peripheral keel; white with a gray-brown periostracum. *Spire:* more than half the length of the shell; protoconch of four narrowly conical whorls, the two abapical whorls axially costate; teleoconch of six or more whorls; suture distinct but not channeled. *Sculpture:* subsutural cord prominent, rounded, smooth; shoulder slope concave with weak spiral threads; peripheral keel prominent, of two noduled cords; last whorl with smooth spiral cords and threads below the periphery; axial growth lines. *Aperture:* sinus broadly V-shaped becoming U-shaped, at the periphery, shallow and occupying full width of peripheral carina; outer lip thin. *Color:* white; periostracum ashy-gray.

This is the most common of the deep-water turrids, recorded by the *Albatross* at depths of from 400 to 1000 m.

G. microscelida was described from the Hawaiian Islands.

Gemmula monilifera (Pease, 1861a). Figs. 111 C; 113 C, D. (Synonym: *Turris aelomitra* "Dall" Tinker, 1952.) Length, 16 mm; diameter, 5 mm. *Shell:* narrowly fusiform; siphonal canal moderately long, almost straight; with peripheral carina strongly gemmate; red-brown, gemmules white. *Spire:* more than half the length of the shell; protoconch of three narrowly conical brown whorls, the apical whorls smooth, the abapical axially costate; teleoconch of eight or nine whorls. *Sculpture:* subsutural

fold narrow; shoulder slope concave with two or three crisp, spiral threads; peripheral carina heavy, studded with two series of axially fused gemmules; last whorl with four smooth primary cords below the carina and weaker threads on the siphonal canal. *Aperture:* sinus moderately deep, U-shaped, its apex the width of the peripheral carina. *Color:* yellow-brown to light red-brown, gemmules of the peripheral carina white, siphonal canal white.

This turrid is most abundant at depths of from 20 to 60 m but is recorded at depths of from 8 to 200 m.

G. monilifera was described from the Hawaiian Islands and has also been recorded from Fiji (Powell, 1964).

Gemmula pseudomonilifera Powell, 1967. Fig. 113 E, F. Length, 17 mm; diameter, 6 mm. *Shell:* narrowly fusiform; siphonal canal moderately long, slightly flexed; peripheral carina strongly gemmate; buff, internodes of peripheral carina light brown. *Spire:* slightly more than half the length of the shell; protoconch of four narrowly conical whorls, the two apical whorls smooth, the abapical whorls closely axially costate; teleoconch of about six whorls. *Sculpture:* subsutural fold prominent, sharply carinated; shoulder slope concave with two fine, smooth threads; peripheral carina low-set with two gemmate cords; last whorl with strong, well-spaced smooth cords and finer interstitial threads below the peripheral carina. *Aperture:* sinus moderately deep, U-shaped, the apex on the peripheral keel. *Color:* ground color buff, suffused with light brown, protoconch and nodes of peripheral keel darker brown.

G. pseudomonilifera was described from the Hawaiian Islands. The species may be allied to *G. hombroni* (Hedley, 1922) from the southwest Pacific (Powell, 1967).

Gemmula tessellata Powell, 1967. (Not figured.) Length, 15 mm; diameter, 9 mm. *Shell:* fusiform; siphonal canal short, straight; prominently noduled; ivory white tessellated with red-brown. *Spire:* slightly more than half the length of the shell; protoconch of four and one-half narrowly conical, red-brown whorls, the apical whorl smooth, the others with axial costae crossed by spiral threads; teleoconch of about six whorls. *Sculpture:* subsutural fold prominent, narrowly crested, tuberculate; shoulder slope deep; peripheral carina massive, of two almost coalescent cords with prominent axially fused nodes; last whorl with widely spaced, flat-topped cords and finer spiral threads below the peripheral carina. *Aperture:* sinus moderately deep, U-shaped, interior of outer lip strongly lirate. *Color:* ivory white tessellated with red-brown; aperture and callus of inner lip white.

This species is known only from the holotype, dredged at a depth of about 200 m off Waikiki, Oahu. Powell (1967) suggests that the shell resembles those of *G. amabilis* (Weinkauff, 1875) from the Red Sea.

Turridrupa albofasciata (Smith, 1877). Figs. 111 J; 113 H. Length, 16 mm; diameter, 7 mm. *Shell:* cylindro-fusiform; solid; siphonal canal truncated; with spiral keels and fine threads between the keels; black. *Spire:* teleoconch of straight, convex whorls two times the height of the aperture plus the canal. *Sculpture:* three strong spiral keels on each whorl, the apical on the subsutural band with three threads, the peripheral keel undulated and thickened where it crosses distant axial folds; the

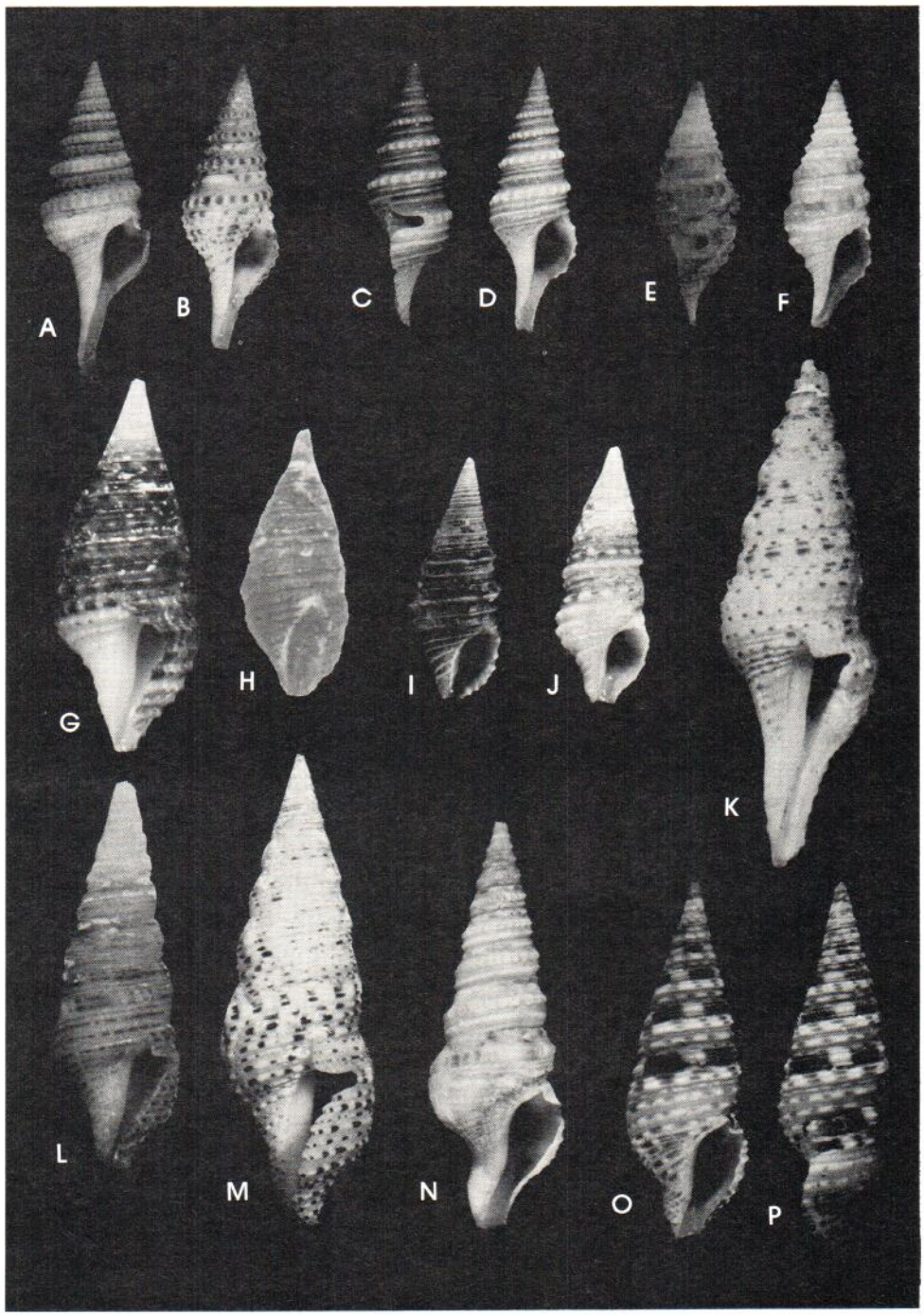


Figure 113.—**Turrinae.** A. *Gemmula congener*, length 31 mm. B. *G. interpolata*, length 25 mm. C, D. *G. monilifera*, length 16 mm. E, F. *G. pseudomonilifera*, length 17 mm. G. *Turridrupa weaveri*, length 18 mm. H. *T. albofasciata*, length 16 mm. I. *T. bijubata*, length 16 mm. J. *T. consobrina*, length 19 mm. K. *Turris crispa intricata*, length 44 mm. L. *Xenoturris castanella*, length 24 mm. M. *X. cerithiformis*, length 29 mm. N. *X. gemmuloides*, length 21 mm. O, P. *X. kingae*, length 23 mm.

abapical cord between the periphery and lower suture smooth; last whorl and fasciole with spiral threads; interstices of keels and cords decussated by axial threads. *Aperture:* suboval; sinus deep, U-shaped. *Color:* black, aperture dark.

These turrids occur at moderate depths of from 20 to 50 m.

This species is also found in the Amami Islands, at Lifu, and in New Caledonia (Powell, 1967). It is distinguished from *T. bijubata* by its strongly undulated peripheral keel, different form of subsutural margin, stronger interstitial spiral threads, and the presence of a pale band between the peripheral and abapical keels.

Turridrupa bijubata (Reeve, 1843). Figs. 111 H; 113 I. Length, 16 mm; diameter, 6 mm. *Shell:* cylindro-fusiform; siphonal canal truncate; with spiral keels and finer threads; brown with lighter spiral sculpture. *Spire:* teleoconch of straight, convex whorls, the whorls twice the height of the aperture plus canal. *Sculpture:* strong, sharply raised spiral keels, three on the spire whorls, one subsutural and slightly weaker than the other two, median cords undulated and slightly thickened at the crests of weak axial folds; last whorl and fasciole with weaker spiral threads; interstices of the keels with crisp spiral threads. *Aperture:* suboval; sinus U-shaped, deep; external sculpture visible in the aperture. *Color:* brown, the spirals often lighter, yellow or tan.

This species occurs at moderate depths of from 20 to 50 m.

T. bijubata is distributed from Mauritius through the Indo-West Pacific to Queensland, New Caledonia, and Fiji (Powell, 1967).

Turridrupa consobrina Powell, 1967. Fig. 113 J. Length, 19 mm; diameter, 7 mm. *Shell:* cylindro-fusiform; solid; siphonal canal truncate; with spiral keels and finer threads between the keels; buff maculated with red-brown. *Spire:* more than two times the length of the aperture and siphonal canal; protoconch of four and one-half conic whorls with arcuate axial ribs crossed by indistinct spiral threads; teleoconch of about 10 whorls. *Sculpture:* strong, narrowly ridged spiral cords, three on the spire whorls, five on the last whorl, with fine threads in the interspaces; last whorl and fasciole with fine threads. *Aperture:* sinus deep, U-shaped, at the termination of the middle cord of the spire whorls; parietal callus pad heavy. *Color:* buff to pale golden-brown, sinus cord conspicuously maculated with darker red-brown spots.

These turrids occur in and under calcareous algae at depths of about 13 m on Maui.

T. consobrina was described from the Hawaiian Islands and also occurs in the Amami-Oshima Islands of southern Japan (Powell, 1967).

Turridrupa weaveri Powell, 1967. Figs. 111 I; 113 G. Length, 18 mm; diameter, 7 mm. *Shell:* cylindro-fusiform; solid; siphonal canal truncated; with spiral keels and fine threads in the interstices; cream-white maculated with red-brown. *Spire:* twice the length of the aperture plus canal; protoconch of two and one-half conical whorls, apical whorl low and dome-shaped, abapical whorls with strong axial ribs; teleoconch of straight, slightly convex whorls. *Sculpture:* three cords plus a fourth emergent on the last whorl; subsutural cord massive, sinus cord about half the strength of the subsutural cord, and the one or two keels below slightly heavier than the sinus cord; last whorl and fasciole with widely spaced threads and finer threads in the interstices.

Aperture: suboval; sinus deep, U-shaped. *Color:* cream-white maculated with red-brown.

Specimens have been dredged at depths of 15 to 300 m off Oahu.

T. weaveri was described from the Hawaiian Islands.

Turris crispa intricata Powell, 1964. Fig. 113 K. Length, 44 mm; diameter, 10 mm. *Shell:* fusiform; solid; with spiral keels; cream-white, spiral cords and threads with dots and dashes of brown. *Spire:* spire of 11 or more whorls, about one and one-half times the length of the aperture plus siphonal canal. *Sculpture:* subsutural band with a pair of spiral cords; sinus rib concave, margined top and bottom by smooth cords; peripheral carina massive, narrowly arched, margined above and below by spiral threads; last whorl and fasciole with larger and smaller spiral threads; cords and threads crossed by axial growth striae. *Aperture:* sinus deep, on a ridge above the peripheral carina. *Color:* creamy white, spiral threads and cords with brown dots and dashes.

Specimens are rare at depths of from 8 to 24 m, more common from 60 to 200 m.

The Hawaiian shells are distinguished from other Indo-West Pacific representatives of the species (*T. c. crispa* from Madagascar to Australia and Fiji, *T. c. yeddoensis* from Japan and the Ryukyu Islands, and *T. c. variegata* from the Indian Ocean) by their small size; prominent, peripheral carina; truncated and twisted siphonal canal; and speckled pattern (Powell, 1964).

Xenoturris castanella Powell, 1964. Fig. 113 L. (Synonym: *Turris castanella* Dall MS, Tinker, 1952.) Length, 24 mm; diameter, 9 mm. *Shell:* fusiform; anterior end truncate; with closely spaced, strong, narrow spiral cords; chestnut brown with darker spirals. *Spire:* one and one-half times the length of the aperture plus canal; protoconch of four and one-half whorls, brown, densely sculptured with slightly curved, strong, rounded axials crossed by weaker spiral threads; teleoconch of ten lightly convex whorls. *Sculpture:* subsutural fold slightly raised with three spiral threads; sinus rib with three threads; two primary cords and finer threads between sinus rib and lower suture; last whorl and fasciole with cords and threads; interspaces of cords obliquely striated. *Aperture:* sinus deep and narrow. *Color:* chestnut-brown, the primary cords darker and with traces of brown maculations on the whorls; parietal callus, columella and interior of aperture white.

This is a rather rare species occurring at depths of 16 to 40 m.

X. castanella was described from the Hawaiian Islands. Powell (1964) notes that it is a member of the *cingulifera* series of species which ranges from the Indian Ocean to southern Japan, New Caledonia, Fiji, and the Marshall Islands.

Xenoturris cerithiformis Powell, 1964. Fig. 113 M. (Synonyms: *Pleurotoma lirata* Pease, 1869b, non *P. lirata* Reeve, 1845; *Turris cerithiformis* Dall MS, Tinker, 1952.) Length, 29 mm; diameter, 8 mm. *Shell:* fusiform; anterior end truncate; sculpture of densely concentrated spiral cords and threads; white speckled with red-brown. *Spire:* twice the length of the aperture plus the canal; protoconch of four or four and one-half brown whorls densely sculptured with slightly curved axial ribs

crossed by spiral lirae; teleoconch of ten to eleven slightly convex whorls. *Sculpture:* subsutural fold broadly convex with three to five weak spiral threads; sinus rib separated from subsutural fold by a deep concavity, with two strong threads; remainder of whorls with cords and threads of varying strength. *Aperture:* sinus deep and narrow; siphonal canal slightly recurved. *Color:* white evenly speckled with red-brown dots and dashes.

Shells are fairly common at depths of from 10 to 80 m.

This species was described from the Hawaiian Islands. Powell (1964) distinguished the Hawaiian shells from those of *X. millepunctatus* (Sowerby, 1908b) from New Caledonia, Fiji, Japan, and Okinawa by their more rounded whorls, less sharply angled base, and less deeply excavated neck.

Xenoturris gemmuloides Powell, 1967. Fig. 113 N. Length, 21 mm; diameter, 7 mm. *Shell:* fusiform; anterior end truncate; siphonal canal flexed; with spiral cords and gemmules on the peripheral carina; dull white, maculated and streaked with reddish brown. *Spire:* almost twice the length of the aperture plus canal; protoconch of three and one-half creamy white, conical whorls, the two apical whorls smooth, the others closely axially ribbed; teleoconch of about ten whorls. *Sculpture:* subsutural fold low, broad, with three crisp spiral threads; sinus keel broad, weakly projecting, of two gemmate cords and an intermediate thread, the gemmules axially fused and closely spaced; two spiral threads below the peripheral carina; last whorl and fasciole with alternating strong and weak spiral threads. *Aperture:* sinus deep, narrow, parallel-sided, occupying the width of the peripheral keel; siphonal canal strongly twisted. *Color:* dull white with angular red-brown spots on the subsutural fold and peripheral carina, remainder of shell maculated and streaked with red-brown.

Shells have been dredged at depths of from 30 to 530 m.

X. gemmuloides was described from the Hawaiian Islands. The shells are distinguished from those of *X. cerithiformis* Powell, 1964 by the gemmate peripheral keel.

Xenoturris kingae Powell, 1964. Figs. 111 F; 113 O, P. Length, 23 mm; diameter, 7 mm. *Shell:* fusiform; anterior end truncate; with spiral cords and threads; creamy white spirally maculated with red-brown. *Spire:* two times the length of the aperture plus canal; protoconch of four and one-half dark brown whorls sculptured by closely spaced, regular axial threads; teleoconch of six or seven convex whorls, the subsutural fold and sinus rib projecting. *Sculpture:* subsutural fold heavy, with two smooth spiral cords; sinus rib projecting, margined above and below with two smooth cords; remainder of whorls with three to six smooth cords of almost equal diameter. *Aperture:* sinus deep, narrow, square-cut; anterior fasciole weak. *Color:* creamy white with brown spots fused into a band on the subsutural fold, and tessellating the other spiral cords.

X. kingae is common, occurring at depths of from 10 to 200 m, but appears most frequently between 20 and 60 m.

This species was described from the Hawaiian Islands. It is distinguished from other members of the *cingulifera* series by the almost complete absence of secondary sculpture and the red-brown maculations on the subsutural fold (Powell, 1964).

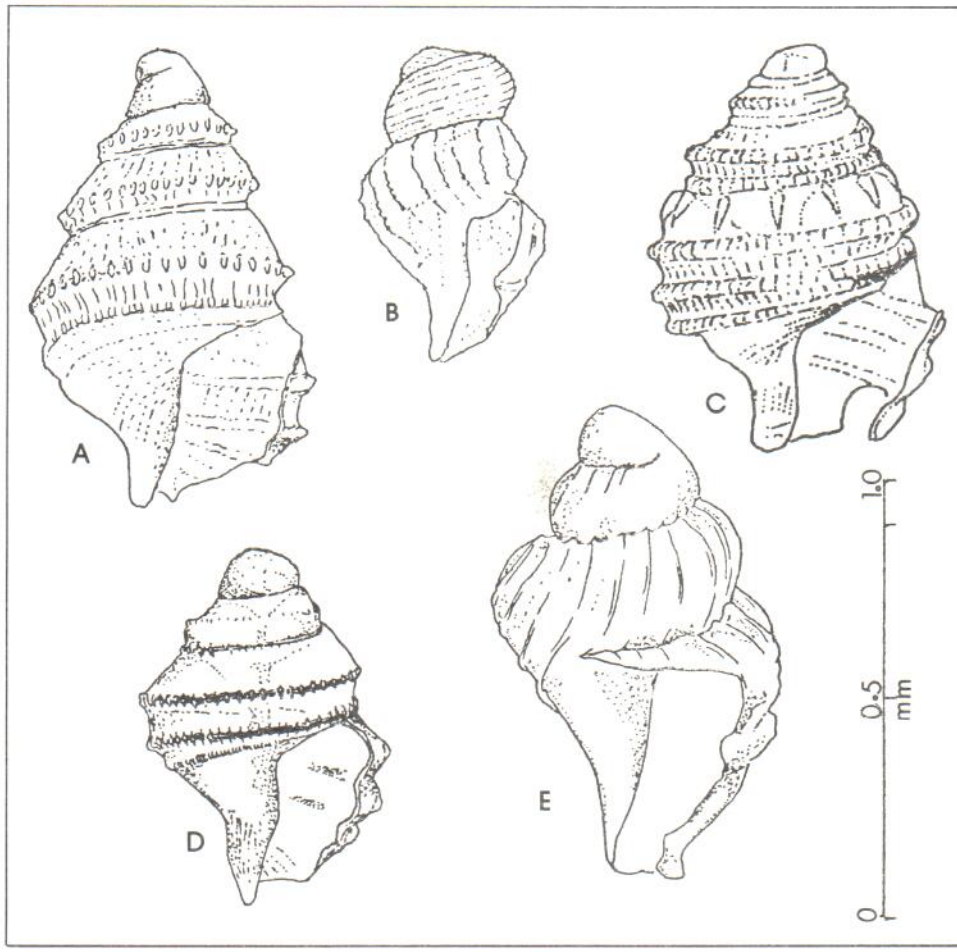


Figure 114.—Premetamorphic protoconchs of turrids. A. *Ceritoturris bittium*. B. Turrid sp. C. *Carinapex minutissima*. D. *Lienardia mighelsi*. E. *Eucithara angiostoma*.

Subfamily **Clavinae**

The shells of the Clavinae are slender and high-spired, with a short, truncate siphonal canal, moderately shallow to subtubular sinus on the shoulder and often have a parietal tubercle. They are small to moderate in size in Hawaii (3 to 15 mm in length). An operculum is present. The radula is distinguished from that of other turrids in that in some species the lateral teeth are comblike (McLean, 1971).

Two types of protoconch occur in the Hawaiian representatives of the subfamily, a paucispiral form perhaps associated with direct development in *Clavus nodifera,* and a conical form associated with a planktonic veliger larval stage in the other species (Fig. 114 C). Six of the seven Hawaiian members of the subfamily are found in tide pools or beach drift, indicating their occurrence in fairly shallow waters; *Ceritoturris bittium* is restricted to deep water at depths of from 50 to 100 m. Three of the seven species are known only from the Hawaiian Islands.

Carinapex minutissima (Garrett, 1873b). Figs. 112 A, G; 114 C; 115 O. Length, 3 mm; diameter, 1 mm. *Shell:* ovate; axial ribs cut into large nodules by spiral grooves; red-brown. *Spire:* protoconch of about four and one-half whorls, the apical one and one-half whorls smooth, the remaining whorls with a prominent, low-set carina; teleoconch of three whorls separated by a linear suture. *Sculpture:* convex, rounded, axial ribs cut by a deep spiral groove into two rows of nodules on each whorl. *Aperture:* narrowly ovate, about one-third the length of the spire; outer lip thickened; sinus subsutural, U-shaped, and with a large callus. *Operculum:* leaf-shaped with a terminal nucleus. *Color:* red brown. *Animal:* exposed parts creamy white. Radula of simple marginals only (Powell, 1966).

This minute turrid is very common under rocks in tide pools and on fringing reefs, and occurs in sediments to depths of 60 m. The veligers are among the most abundant veligers in the plankton at Kaneohe Bay, Oahu; they metamorphose easily under culture conditions but do not grow much beyond their size at metamorphosis (length, 825 μm, width, 560 μm) which suggests that they may be food specialists (J. B. Taylor, 1975). The premetamorphic protoconch has beaded spiral keels on the second, third, and fourth whorls and axial ribs on the third and fourth whorls (J. B. Taylor, 1975).

C. minutissima was described from Fiji, and shells resembling those from Hawaii also occur in New Caledonia.

Carinapex papillosa (Garrett, 1873b). Fig. 115 P. Length, 2.5 mm; diameter, 1 mm. *Shell:* biconic; with prominent beads; light yellow-brown. *Spire:* protoconch of three and one-half conical whorls, the two abapical whorls carinate; teleoconch of four whorls, slightly inflated; suture impressed, wide. *Sculpture:* two spirals of prominent circular beads joined by axial columns on the apical whorls, last whorl with three beaded spirals and prominent spiral cords; beads circular and spaced about their own diameter apart. *Aperture:* ovate; with a thick, sutural sinus; siphonal canal and columella straight. *Color:* apical whorls and base white, other whorls light yellow-brown.

These turrids are occasionally found in beach drift on southern beaches on Oahu, and in sediments to depths of about 30 m.

C. papillosa was described from Tahiti.

Ceritoturris bittium Dall, 1924. Figs. 114 A; 115 Q. Length 7 mm; diameter, 2.5 mm. *Shell:* claviform, slender; with axial folds crossed by narrow spiral cords; light red-brown. *Spire:* protoconch of one and one-half smooth, low conical whorls followed by two whorls with a sharp median carina; teleoconch of seven whorls; suture shallow. *Sculpture:* distant axial ribs (about 10 on the last whorl) overridden by three to five narrow spiral cords, the peripheral cord and the one below it rendering the axials subspinose. *Aperture:* narrow, about one-third the length of the spire; siphonal canal short, unnotched, slightly recurved; outer lip thickened; sinus subsutural, deep, U-shaped, constricted by a parietal callus. *Color:* light red-brown.

These turrids are found in sediments at depths of from 50 to 100 m.

C. bittium was described from the Hawaiian Islands.

Clavus rissoiniformis Kay, new species. Fig. 115 L. Length, 7 mm; diameter, 2.5 mm (holotype). *Shell:* fusiform-ovate, apex tapering; with fine axial threads; cream.

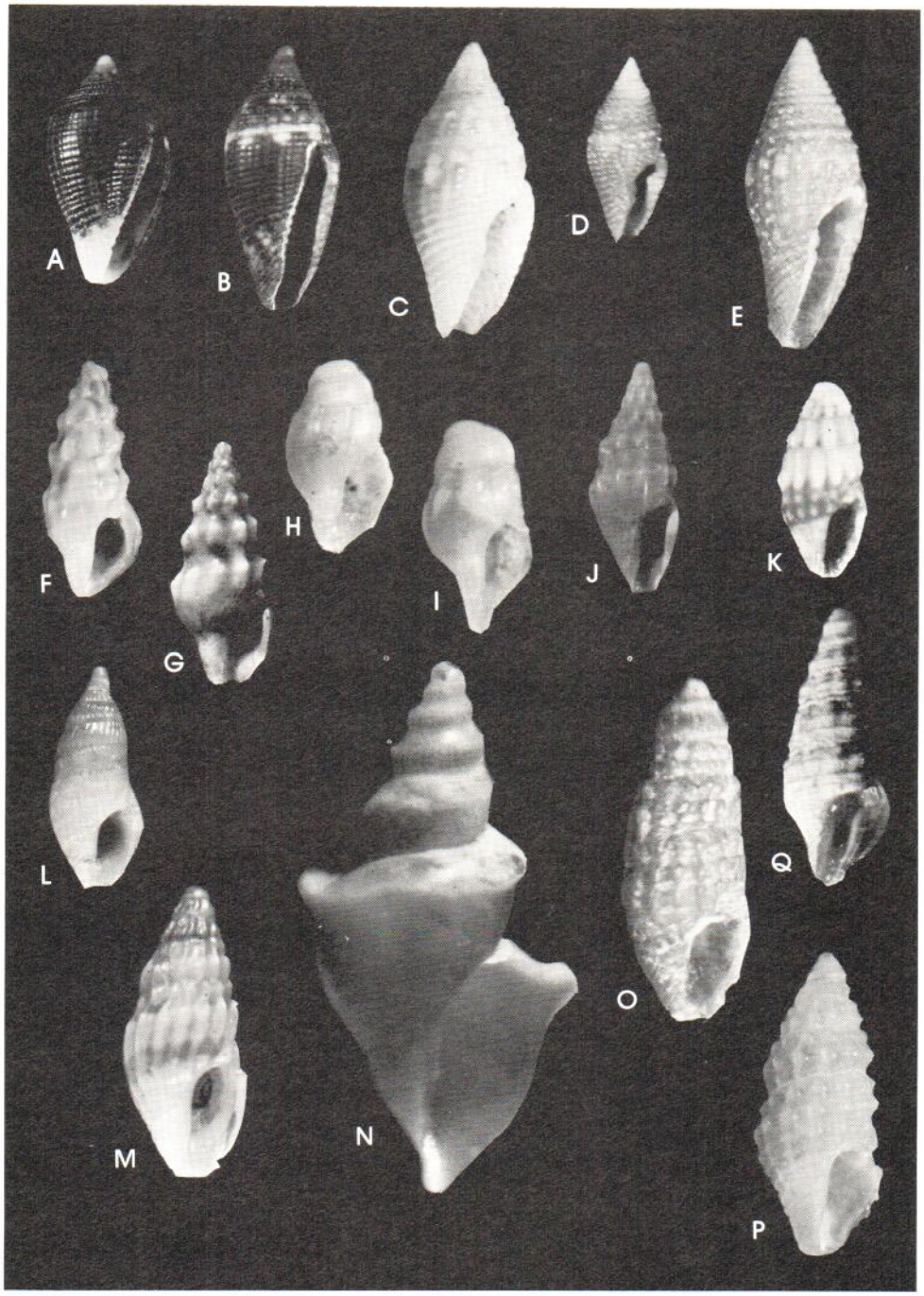


Figure 115.—A. *Lovellona atramentosa*, length 8 mm. B. *L. peaseana*, length 6 mm. C. *Mitrolumna metula*, length 6 mm. D. *M. iki*, length 3.5 mm (holotype). E. *M. alphonsiana*, length 4.5 mm. F. *Clavus laeta*, length 10 mm. G. *C. nodifera*, length 12 mm. H, I. juvenile shells of *Clavus* spp. showing different styles of protoconch. J. *C. mighelsi*, length 7 mm. K. *C. pusilla*, length 4 mm. L. *C. rissoiniformis*, length 7 mm (holotype). M. *C. powelli*, length 5.5 mm (holotype). N. *Thatcheriasyrinx* sp., length 4 mm. O. *Carinapex minutissima*, length 3 mm. P. *C. papillosa*, length 3 mm. Q. *Ceritoturris bittium*, length 7 mm.

Spire: protoconch of two smooth, blunt whorls; teleoconch of five somewhat inflated whorls; suture distinct. *Sculpture:* numerous threadlike axial threads extending from the suture to the base, with subequal interspaces; spiral sculpture of a constriction in front of the suture forming a subsutural band. *Aperture:* ovate, wide; sinus conspicuous; outer lip thick but not varicose; smooth within. *Color:* cream to light yellow-brown.

Specimens have been dredged at depths of 66 to 100 m.

Type locality: Kepuhi Point, Oahu, at the base of a cliff, depth 60 m. *Holotype:* B. P. Bishop Museum No. 9812. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum; R. Salisbury collection.

The narrow axial ribs, reminiscent of those of a rissoinid, and yellow-brown color distinguish these shells from others in the genus. Derivation of name: *Rissoina,* genus of mesogastropods; *formis* from the Greek — in the form of. Refers to the superficial resemblance to *Rissoina*.

Clavus (Splendrillia) laeta (Hinds, 1843). Fig. 115 F. Length, 15 mm; diameter, 6 mm. *Shell:* high-spired, truncate anteriorly; with broad, blunt axial ribs; white spirally banded with a brown thread. *Spire:* protoconch not known; teleoconch of five barely convex whorls; shoulder slope descending broadly, slightly concave; suture shallow, wide. *Sculpture:* surface smooth and glossy; axial sculpture of strong, blunt axial ribs, about eight on the last whorl. *Aperture:* broadly ovate, about one-quarter the length of the spire; outer lip thin at the edge, thickened behind by an axial rib; siphonal canal short, straight. *Color:* white, broadly banded with brown and with a narrow brown spiral on the periphery of the last whorl.

Shells are uncommon in beach drift.

C. laeta was described from the "China Seas."

Clavus (Splendrillia) nodifera (Pease, 1860). Fig. 115 G. Length, 12 mm; diameter, 5 mm. *Shell:* high-spired, truncate anteriorly; with axial ribs becoming nodular at the periphery of the last whorl; white spirally banded with brown. *Spire:* protoconch of at least two smooth, white whorls; teleoconch of five barely convex whorls; suture shallow and wide, the shoulder slope wide and descending steeply. *Sculpture:* surface smooth and glossy; axial sculpture of strong, projecting peripheral nodes which become obsolete on the last whorl. *Aperture:* broadly ovate, about one-third the length of the spire; outer lip thin at the edge, slightly thickened behind; sinus deep with a prominent parietal callus; siphonal canal short, straight, and with a shallow notch. *Color:* white with a broad brown band spiralling about the periphery of the last whorl and splashes of brown at the interspaces between the ribs and below the periphery of the last whorl.

Shells are occasionally found in beach drift and the animals appear to live at depths of about 20 m.

C. nodifera was described from the Hawaiian Islands.

Clavus (Tylotiella) mighelsi Kay, new name. Fig. 115 J. (Synonym: *Pleurotoma acuminata* Mighels, 1845, non Sowerby, 1816.) Length, 11 mm; diameter, 5 mm. *Shell:* ovate-fusiform, solid, smooth; with thick, sinuous axial ribs; brown banded with

a narrow white spiral below the suture. *Spire:* protoconch of one and one-half smooth whorls; teleoconch of four or five barely convex whorls; suture shallow, barely impressed. *Sculpture:* surface smooth, glossy; with thick, sinuous, convex axial ribs extending to the base of the last whorl, interspaces shallow and of lesser diameter than the ribs; a spiral thread cuts the ribs just below the suture. *Aperture:* narrow, about one-third the length of the spire; outer lip thin; sinus deep, U-shaped, with a parietal callus. *Color:* brown with a spiral white thread below the suture.

These turrids are common in beach drift, especially along the shores of northern beaches and on fringing reefs.

C. mighelsi was described from the Hawaiian Islands (as *Pleurotoma acuminata*).

Clavus (Tylotiella) powelli Kay, new species. Fig. 115 M. Length, 6 mm; diameter, 2.25 mm. *Shell:* fusiform, ovate; solid; with bold axial ribs; white spirally banded with yellow-brown. *Spire:* protoconch of two smooth, conical whorls; teleoconch of five barely convex whorls; suture impressed; shoulder slope concave. *Sculpture:* smooth and glossy, with narrow, rather sharp axial ribs, the interspaces of about the same diameter as the ribs, ribs nodulose below the suture. *Aperture:* wide, ovate; outer lip thin at the edge, with a varix behind; siphonal canal straight. *Color:* glossy, white, spirally banded below the periphery of the last whorl with yellow brown.

These turrids are common at depths of 120 to 140 m.

Type locality: Pokai Bay, Oahu, from 120 to 140 m. *Holotype:* Bernice P. Bishop Museum No. 9814. *Paratype:* R. Salisbury collection.

The shells of this turrid are distinguished from those of its congeners by the neatly arranged axial ribs and distinctive color pattern. This species is named for A. W. B. Powell, whose studies of the Turridae are unparalleled in any other group of marine mollusks.

Clavus (Tylotiella) pusilla (Garrett, 1873b). Fig. 115 K. (Synonym: *Drillia exilis* Pease, Edmondson, 1946.) Length, 4 mm; diameter, 1.5 mm. *Shell:* fusiform-ovate; with straight, smooth axial ribs; white spirally banded with chestnut brown on the last whorl. *Spire:* protoconch of four and one-half smooth, conical, white whorls; teleoconch of three or four rather straight-sided whorls separated by a shallow, linear suture. *Sculpture:* vertical axial ribs slightly indented below the suture, the interspaces smooth, deep, and of lesser diameter than the ribs. *Aperture:* narrowly ovate, about one-third the length of the spire; sinus shallow, with a heavy parietal callus. *Color:* white with a wide spiral band of chestnut brown below the periphery of the last whorl ending midway across the outer lip, and splashes of brown at the suture.

C. pusilla is common in shallow water under rocks in tide pools and on fringing reefs.

This species occurs throughout the Indo-West Pacific, from Zanzibar and Madagascar to the Cocos-Keeling Islands (Maes, 1967, as *Iredalea pygmaea* Dunker, 1860), and in New Caledonia, Palau, and Polynesia. Garrett (1873b) distinguished the shells from another widespread Indo-West Pacific form, *I. pygmaea* (Dunker, 1860), by the more slender form, longer spire, and distinctly constricted suture.

Subfamily **Mitrolumninae**

This subfamily, recognized by Sacco (1904), was distinguished by McLean (1971) to include relatively small shells with the axial and spiral sculpture of about equal strength, with prominent to obsolete folds on the columella (forming V-shaped folds in Hawaiian species), with a shallow sinus consisting merely of an indentation next to the suture, and with the anterior end usually truncate. The teeth are toxoglossate; Maes (1967) describes the radular formula of *Mitromorpha stepheni* (Melvill and Standen, 1897), which has a shell similar to that of *M. metula* found in the Hawaiian Islands, as 1-0-0-0-1. There is no operculum.

Lovellona atramentosa (Reeve, 1849). Fig. 115 A. Length, 8 mm; diameter, 4 mm. *Shell:* ovate-biconic; with flat, low, spiral cords and axial threads; dark brown, anterior tip white. *Spire:* protoconch paucispiral, of one and one-half smooth, white whorls; teleoconch a broad, low conical spire, narrowly convex at the periphery, tapering at the base and with the suture barely impressed. *Sculpture:* apical whorls granular, remaining whorls encircled by flat, low cords, the interspaces with fine grooves and with axial threads. *Aperture:* elongate, longer than spire; outer lip thin, marked by the spiral sculpture; columella straight. *Color:* dark brown, anterior canal tipped with white, and with a row of white spots on the periphery of the last whorl.

L. atramentosa is known only from shells found in beach drift along the shores of northern beaches.

This species is widely distributed in the Indo-West Pacific, from Zanzibar to the Philippines and Queensland (Powell, 1966).

Lovellona peaseana Finlay, 1927. Fig. 115 B. (Synonyms: *Conus fusiformis* Pease, 1861a; *C. parvus* Pease, 1868e.) Length, 6 mm; diameter, 3 mm. *Shell:* ovate-biconic; encircled with flat spiral cords and narrow axial grooves; brown, sutural margin cream. *Spire:* protoconch paucispiral, of one and one-half globose, smooth, brown whorls; teleoconch of five whorls, narrowly rounded periphery, and tapering base; suture barely impressed. *Sculpture:* apical whorls granular; remaining whorls encircled by spiral grooves sculptured by microscopic axial threads; with a subsutural band of a raised spiral cord and two obsoletely granular cords. *Aperture:* elongate, longer than spire; outer lip thin; columella straight. *Color:* dark brown with a row of irregular cream or white spots on the periphery of the last whorl, margin of suture light yellow.

Shells are common in beach drift but living animals are only occasionally found under rocks in tide pools and in shallow water shoreward of fringing reefs. This species has a nonplanktonic larva.

L. peaseana appears to be rather widely distributed in the Indo-West Pacific. It is distinguished from *L. atramentosa* by its smaller size, sutural band, and lack of a white-tipped base.

Mitrolumna alphonsiana (Hervier, 1899). Fig. 115 E. (Synonym: *Mitrolumna salisburyi* Cernohorsky, 1978a.) Length, 4.5 mm; diameter, 2 mm. *Shell:* ovate-biconic; apical whorls with spirals of beaded threads, last whorl with weak, beaded

axial ribs and spirals; mauve to lavender brown, spirally banded with yellow and with white subsutural nodules on the last whorl. *Spire:* protoconch of three and one-half smooth, conical brown whorls; teleoconch of five slightly inflated whorls; suture indistinct. *Sculpture:* axial sculpture of low, rather weak axial ribs, about 24 on a last whorl 2 mm in diameter; ribs on the last whorl and the apical whorls with three or four rows of beaded spiral cords, the beads on the last whorl forming a row of subsutural nodules. *Aperture:* narrow, about equal in length to the spire; turrid sinus a shallow notch; outer lip thin, lirate within and constricted medially by a thick pad; columella with a V-shaped fold in the center. *Color:* mauve to lavender, spirally banded below the suture with yellow on the apical whorls and on the last whorl with the subsutural nodules white.

These turrids are uncommon at depths of about 60 m.

The Hawaiian shells have been compared with the holotype of *Columbella alphonsiana*, described from Lifu, Loyalty Islands. The holotype is worn and smooth but the sculptural and color patterns are so similar to those of the Hawaiian shells that they are considered conspecific.

Mitrolumna iki Kay, new species. Fig. 115 D. Length, 3.5 mm; diameter, 1.5 mm (holotype). *Shell:* ovate-biconic; with feeble axial ribs crossed by spiral threads, usually nodular at the junctions; yellow-brown, apex and aperture white. *Spire:* protoconch of four and one-half conical, smooth, white whorls; teleoconch of three barely inflated whorls; suture indistinct. *Sculpture:* axial sculpture of low, rather closely set, feeble ribs, 10 on the last whorl, ribs becoming obsolete on the base; spiral sculpture of flat threads crossing the ribs, nodular at the junctions on the apical whorls but obsolete or absent below the periphery of the last whorl. *Aperture:* narrow; about equal in length to the spire; turrid sinus strong, shallow; outer lip thin, lirate within and constricted medially by a thick pad; columella with a V-shaped fold in the center. *Color:* yellow-brown, apex and aperture white, and with at least one and sometimes two rows of white granules beneath the suture on the last whorl.

These turrids are found at depths of about 60 m.

Type locality: Kepuhi Point, Oahu, at a depth of 60 m, June, 1977. *Holotype:* B. P. Bishop Museum No. 96824. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The shells of *M. iki* are distinguished from those of other species in the genus by their color pattern (other described *Mitrolumna* are white with brown blotches or brown-pink with lavender); protoconch of four and one-half whorls (other described *Mitrolumna* have three whorls in the protoconch); and small size. Derivation of name: *iki*, Hawaiian — small. Refers to the small size compared with other species in the genus in Hawaii.

Mitrolumna metula (Hinds, 1843). Fig. 115 C. (Synonyms: *Cythara garrettii* Pease, 1860; *Columbella lacrima* Gaskoin, Martens and Langkavel, 1871.) Length, 6 mm; diameter, 2 mm. *Shell:* fusiform, solid; with axial ribs interlaced with spiral cords; white with yellow or brown splashes. *Spire:* protoconch of three and one-half smooth, conical, white whorls; teleoconch of four whorls, the last the largest; suture faintly impressed. *Sculpture:* axial ribs interlaced with spiral cords, the ribs and spirals

producing a ladderlike effect; apical whorls with beaded spiral threads; base with eight spiral bands separated by axially striated depressions. *Aperture:* narrow, about equal in length to the spire; outer lip thin, constricted medially by a thick pad, lirate within; columella with a V-shaped notch. *Color:* white splashed with brown on the apertural surface and with a large brown blotch on the back.

These gastropods are common, found on the undersurfaces of rocks in tide pools and in the shallow waters inshore of fringing reefs; shells have been dredged to depths of 60 m.

M. metula is widely distributed in the Indo-West Pacific; Maes (1967) records the species (as *Mitromorpha lachryma* (Reeve, 1845)) from the Cocos-Keeling Islands, Indian Ocean.

Subfamily **Mangeliinae**

This is a large group of ovate, biconic, or fusiform shells with a short or relatively short anterior canal and a shallow to moderately deep, sometimes subtubular sinus situated on the shoulder slope. The aperture is simple, and the outer lip thin with a terminal varix. The protoconch is smooth to elaborately sculptured (*Eucithara*). There is no operculum. The radula is toxoglossate, the marginal teeth hollow and with an irregular swelling.

Of the thirteen species reported here, ten are found in tide pools or known from beach drift, suggesting a rather shallow habitat. Two species, *Etrema acricula* and *Eucithara pusilla,* are found in sediments at depths of from 10 to 40 m, and *Glyphostoma kihikihi* occurs at depths of more than 100 m. Five of the thirteen species are known only from records of Hawaiian shells; the others are apparently widespread in the Pacific, and three, *Lienardia fenestrata, L. mighelsi,* and *Macteola segesta,* are also known from the Indian Ocean.

Anacithara perfecta Kay, new species. Fig. 116 A. Length, 3.25 mm; diameter, 1.5 mm (holotype). *Shell:* fusiform, blunt; with broad axial ribs crossed by microscopic spiral threads; white spotted with brown at the suture. *Spire:* protoconch of two and one-quarter glistening, smooth whorls; teleoconch of three inflated whorls, suture impressed and crenulated by the axial ribs. *Sculpture:* prominent, broadly rounded axial ribs, about 10 on the last whorl; crisp spiral threads, between which are microscopic axial threads, override the ribs. *Aperture:* ovate, less than one-half the length of the spire; outer lip with a strong foldlike varix; columella straight; sinus on shoulder broad and shallow. *Color:* cream white, lightly spotted with brown between the ribs at the suture and with a brown spot on the outer lip.

These turrids are found at depths of 10 to 20 m and shells are occasionally seen in beach drift along the shores of northern beaches.

Type locality: Anaehoomalu Bay, Hawaii Island, depth of 9 m. *Holotype:* Bernice P. Bishop Museum No. 9816.

The Hawaiian shells are of the same general form and sculpture as those of *Anacithara naufraga* (Hedley, 1922) from Queensland, Australia, but are distinguished

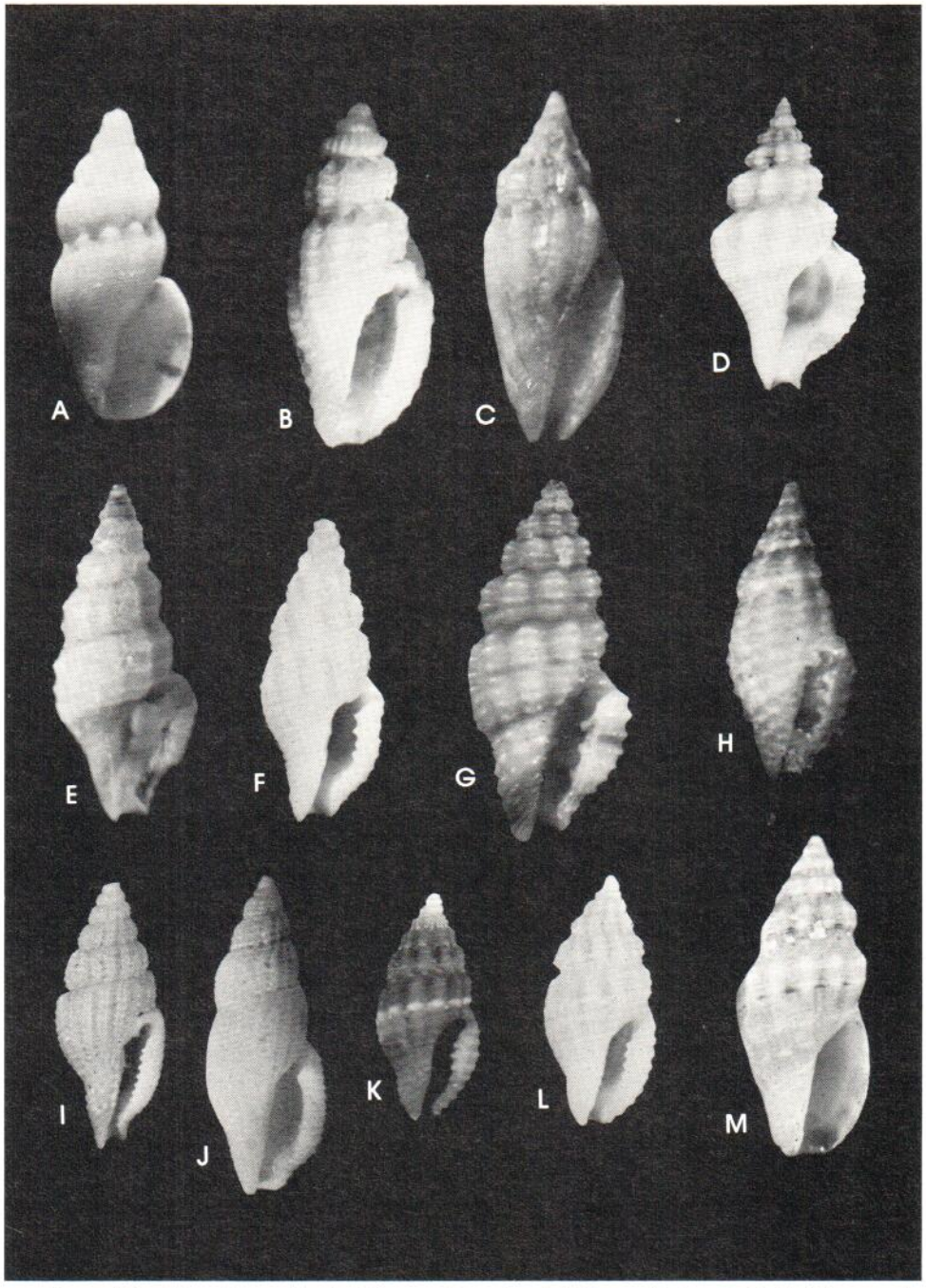


Figure 116.—**Mangeliinae.** A. *Anacithara perfecta,* length 3.25 mm (holotype). B. *Eucithara angiostoma,* length 5 mm. C. *E. pusilla,* length 4 mm. D. *Glyphostoma kihikihi,* length 5 mm (holotype). E. *Etrema acricula,* length 4 mm. F. *Lienardia crassicostata,* length 7 mm. G. *L. mighelsi,* length 7 mm. H. *L. fenestrata,* length 5 mm. I. *L. lutea,* length 8 mm. J. *Paramontana exilis,* length 5 mm. K. *Lienardia balteata,* length 5 mm. L. *L. apiculata,* length 5 mm. M. *Macteola segesta,* length 6 mm.

by their smaller size and the neatly crenulated suture. Derivation of name: *perfecta*, Latin — perfect. Refers to the neat, miniature form and sculpture.

Etrema acricula Hedley, 1922. Fig. 116 E. Length, 4 mm; diameter, 1 mm. *Shell:* biconic, turreted; with broad axial ribs and coarse spiral threads; buff, spirally banded with orange-brown on the base. *Spire:* protoconch of four and one-half to five and one-half whorls, the apical one and one-half whorls smooth, the others turreted and with a strong spiral keel; teleoconch of three inflated whorls, angled at the shoulder; suture shallow. *Sculpture:* low, narrow, rather distant axial ribs, about 12 on the last whorl, extending from shoulder to base; below the shoulder angle three or four spiral threads cross the ribs. *Aperture:* ovate; varix prominent, formed of the last rib which folds into the aperture, externally with six spiral cords, internally with three tubercles; sinus excavated, at an oblique angle to the aperture; columella with three plaits. *Color:* buff, apex light orange; aperture and base spirally banded with orange-brown and with a dark brown spiral at the suture.

Shells are common in beach drift along shores of northern beaches and at depths of from 15 to 40 m.

E. acricula was described from Murray Island, Queensland, Australia. Hedley (1922) noted that the prominence of the varix inclines the shell toward a hatchetlike form, which is quite characteristic of the Hawaiian shells.

Eucithara angiostoma (Pease, 1868e). Fig. 114 E; 116 B. Length, 5 mm; diameter, 2 mm. *Shell:* lyriform, slender; with bold axial ribs crossed by thin spiral threads; white banded with brown on the back. *Spire:* protoconch of three and one-half whorls, the two apical whorls smooth, the other with oblique axial threads; teleoconch of four inflated, angular whorls; suture shallow, shelf sloping. *Sculpture:* axial ribs lyriform, sharp, the interspaces of about the same diameter as the ribs; ribs and interspaces crossed by fine spiral threads separated by reticulated interspaces of greater diameter. *Aperture:* narrow, half the length of the spire; outer lip with a varix and denticulate within; sinus well developed. *Color:* white with a brown band on the back of the last whorl.

These turrids are often common in beach drift. There is a six-lobed veliger larva, found in the plankton from April to October; metamorphosis occurs when four whorls are almost complete (J. B. Taylor, 1975).

Pease introduced *angiostoma* as a new name for *triticea* Kiener in Reeve, 1843, non Kiener, 1839, for the "Polynesian form." Shells are common throughout the Pacific, found, for example, in beach drift in Palau.

Eucithara pusilla (Pease, 1860). Fig. 116 C. Length, 4 mm; diameter, 2 mm. *Shell:* ovate, solid; with lyriform axial ribs and faintly striated interspaces; cream banded with dark brown. *Spire:* protoconch of three whorls, the two apical whorls smooth, the abapical whorl with oblique lirae; teleoconch of four convex whorls separated by a deeply impressed suture. *Sculpture:* bold, slightly oblique axial ribs which are angular just below the periphery and separated by interspaces of about equal diameter; ribs and interspaces cut by fine spiral grooves. *Aperture:* elongate, wide; about two-thirds the length of the spire; outer lip with a varix and denticulate within; sutural sinus shallow; columella with folds the entire length. *Color:* cream with wide

bands of dark brown below the suture and around the periphery of the last whorl; outer lip white, interior sometimes stained with brown.

These shells are uncommon, found at depths of 10 to 40 m.

E. pusilla was described from the Hawaiian Islands.

Glyphostoma kihikihi Kay, new species. Fig. 116 D. Length, 12 mm; diameter, 6 mm (holotype). *Shell:* fusiform, broadly ovate; with axial folds and crisp spiral cords; cream with dark brown on the base and shoulder. *Spire:* protoconch of three and one-half conical, unicarinate, white whorls; teleoconch of about five angled whorls with concave shoulders; suture shallow. *Sculpture:* broad axial ribs, about nine on the last whorl, the interspaces shallow and about the same diameter as the ribs; ribs and interspaces overridden by closely spaced, crisp spiral threads, the interspaces microscopically punctate; base with faintly beaded spiral threads. *Aperture:* about half the length of the spire; outer lip with a flaring varix; sinus wide, deep; columella with two plaits. *Color:* cream-yellow, banded with irregular dark brown mottling on the shoulder and on the base of the last whorl.

These turrids are rare, found at depths of about 140 m and occasionally in beach drift.

Type locality: Pokai Bay, Oahu, dredged at 140 m, April 16, 1977, R. Salisbury. *Holotype:* (figured) B. P. Bishop Museum No. 96818. *Paratypes:* B. P. Bishop Museum.

The Hawaiian shells appear to be unique representatives of an otherwise west American genus. Dr. James McLean (pers. comm.) notes "an uncanny resemblance to *G. myrae* Shasky, 1971" from the west coast of America (Jicarita Island, and Panama to Gorgona Island, Colombia), but the Hawaiian shells are distinguished by their broader form, irregular brown mottling on the shoulder, coarser and less numerous spiral cords on the early whorls, and one less whorl of the teleoconch in mature shells. Derivation of name: *kihikihi,* Hawaiian — angular. Refers to the distinctly angled whorls.

Lienardia (Hemilienardia) apiculata (Montrouzier, 1864). Fig. 116 L. Length, 5 mm; diameter, 2.5 mm. *Shell:* biconic, convex; with broadly rounded axial ribs crossed by crisp spiral cords; white. *Spire:* protoconch of three and one-half peglike, smooth, white whorls; teleoconch of four or five inflated, slightly angular whorls; suture shallow and sloping. *Sculpture:* prominent, broad, rounded axial ribs with shallow interspaces approximately equal in diameter crossed by coarse, crisp spiral cords becoming somewhat nodular where they cross the axial ribs. *Aperture:* narrow, about one-third the length of the spire; outer lip with a varix composed of a double rib, the free rib traversed by eight spirals and the edge with four or five denticles; sinus subsutural, deep, U-shaped. *Color:* white with an opaque white spiral thread peripherally on the last whorl.

This is a common shallow-water form, found under rocks in tide pools and on benches subject to considerable wave action.

L. apiculata was described from Lifu, Loyalty Islands, and occurs throughout the Indo-West Pacific from the Seychelles in the Indian Ocean to Irian, New Guinea, and New Caledonia.

Lienardia (Hemilienardia) balteata (Pease, 1860). Fig. 116 K. Length, 5 mm; diameter, 2.5 mm. *Shell:* biconic, inflated; with broadly rounded axial ribs crossed by crisp spiral cords; chestnut spirally banded with white. *Spire:* protoconch of three peglike white whorls, the apical whorl smooth, remaining two with faint granular costae; teleoconch of four to five somewhat inflated whorls; suture shallow and sloping. *Sculpture:* wide, rounded axial ribs, the interspaces shallow and subequal; ribs and interspaces crossed by crisp spiral cords separated by spaces of about equal diameter; fasciole granular. *Aperture:* narrow; outer lip varied and dentate within; sinus deep, subsutural, U-shaped. *Color:* apex white, remainder of shell chestnut with a narrow thread of white spiralling around the last whorl, the white band becoming wider on the last whorl.

These turrids are common in shallow water, found under rocks in tide pools subject to considerable surf action.

L. balteata was described from the Hawaiian Islands.

Lienardia crassicostata (Pease, 1860). Fig. 116 F. Length, 7 mm; diameter, 2.5 mm. *Shell:* biconical, slender; with coarse axial ribs overridden by sharp spiral cords; white, pink or yellow. *Spire:* protoconch of two large white whorls, the apical smooth, the abapical distinctly carinate; teleoconch of five slightly convex whorls; suture shallow, wide, and sloping. *Sculpture:* coarse axial ribs with interspaces equal in diameter, the ribs and interspaces crossed by coarse, sharp spiral cords. *Aperture:* narrow; less than half the length of the spire; outer lip with a heavy varix and four denticles within; sinus deep, subsutural, U-shaped. *Color:* uniform white, pink, or yellow.

Shells are known only from beach drift, and nothing is known of the habits of the living animals.

L. crassicostata was described from the Hawaiian Islands but also occurs in the Tuamotus. The shells are distinguished from those of *L. fenestrata* by their wider, shallower suture, by the cords on the siphonal canal, and the larger, unicarinate protoconch.

Lienardia fenestrata (Melvill, 1898). Fig. 116 H. Length, 5 mm; diameter, 2 mm. *Shell:* biconic, slightly inflated; with broadly rounded axial ribs crossed by crisp spiral cords; white. *Spire:* protoconch of one and one-half smooth, white, bluntly rounded whorls; teleoconch of four convex whorls; suture deeply impressed and channeled. *Sculpture:* prominent, broad, rounded axial ribs with shallow interspaces about the same diameter crossed by coarse, crisp spiral cords. *Aperture:* narrow, about one-third the length of the spire; with a heavy varix and denticulate within. *Color:* white, or white spirally banded with brown below the suture and on the periphery of the last whorl.

Shells are uncommon in beach drift and nothing is known of the habits of the living animals.

L. fenestrata was described from Aden and also occurs in Palau.

Lienardia lutea (Pease, 1860). Fig. 116 I. Length, 8 mm; diameter, 4 mm. *Shell:* biconic-fusiform; with granular axial ribs crossed by spiral cords; cream. *Spire:* protoconch of one and one-half obliquely tilted, mammillate whorls; teleoconch of five

convex whorls; suture impressed and channelled; base constricted. *Sculpture:* strong, somewhat obliquely set axial ribs (about 16 on the last whorl) with interspaces of equal diameter or slightly wider and smooth strong spiral cords rendering the ribs nodulose where they cross; interspaces finely axially striate. *Aperture:* narrowly ovate; about one-third the length of the spire; sinus wide and prominent; outer lip denticulate within; siphonal canal short, recurved.

Beachworn shells are occasionally found on Oahu and in the leeward islands.

L. lutea was described from the Hawaiian Islands and has been recorded from Queensland (Hedley, 1922), Lifu, southern Japan, and the Marshall Islands.

Lienardia mighelsi Iredale and Tomlin, 1917. Figs. 112 C, D; 114 D; 116 G. (Synonym: *Pleurotoma rugosa* Mighels, 1845.) Length, 7 mm; diameter, 3 mm. *Shell:* biconic, turreted; with coarse axial ribs crossed by keeled spiral cords; tan spirally banded with dark brown at the suture. *Spire:* protoconch of three dark brown whorls, the apical smooth and the others with beaded carina; teleoconch of four or five angled, shouldered whorls; suture shallow and sloping. *Sculpture:* broad axial ribs with shallow interspaces of lesser diameter; ribs and interspaces crossed by sharp, keeled spiral cords, the interspaces between the spirals of equal diameter and smooth. *Aperture:* narrow, about one-third the length of the spire; outer lip with a varix and internally denticulate; sinus subsutural, deep, U-shaped. *Color:* fawn or tan, spirally banded with dark brown at the shoulders and peripherally and basally on the last whorl. *Animal:* siphon yellow and rust edged with black; foot white splashed with opaque white, yellow, and rust. Radula of long, slender pointed awl-shaped marginals (Powell, 1966).

These turrids are common in shallow water under rocks in tide pools and on benches subject to considerable surf action.

L. mighelsi occurs through the Indo-West Pacific from the Seychelles and Ceylon to southern Japan and Polynesia.

Macteola segesta (Chenu, 1850). Fig. 116 M. (Synonym: *Daphnella bella* Pease, 1860.) Length, 6 mm; diameter, 2.5 mm. *Shell:* biconic, whorls angulate; with broadly rounded axial ribs and fine spiral striae; cream spirally banded and lineated with yellow and brown. *Spire:* protoconch of two smooth, white whorls; teleoconch of four or five shouldered, angular whorls; suture shallow and linear. *Sculpture:* broad axial ribs more prominent on the periphery of the last whorl than elsewhere, interspaces slightly narrower; ribs and interspaces crossed by fine spiral striae. *Aperture:* subovate; anterior canal short, unnotched; outer lip thin. *Color:* cream spirally banded with black-brown between the axial ribs and lineated with yellow or with spirals of chestnut dashes on the base.

These turrids are common under rocks in tide pools subject to heavy surf action; specimens have also been dredged from depths of 132 to 200 m.

This species is distributed throughout the Indo-West Pacific, recorded from Mauritius, Queensland, Lifu, the Kermadec Islands, Tahiti, and the Tuamotus (Hedley, 1922).

The shells of *M. segesta* superficially resemble those of the mitrid *Vexillum interruptum* in shape, size, and general coloration but are distinguished by the lack of columellar folds, and cream rather than white background.

Paramontana exilis (Pease, 1860). Fig. 116 J. Length, 5 mm; diameter, 2.5 mm. *Shell:* elongate-fusiform; with fine axial ribs crossed by spirals, barely tuberculate at the junctions; white. *Spire:* protoconch of one and one-half bulbous, oblique white whorls; teleoconch of four or five barely convex whorls; suture oblique, shallow. *Sculpture:* fine axial ribs crossed by equally fine spiral threads, the junctions of ribs and spirals barely noduled. *Aperture:* ovate, less than half the length of the spire; outer lip with a varix crossed by the spirals of the external sculpture, internally denticulate. *Color:* white.

Shells of these turrids are not uncommon in beach drift.

P. exilis was described from the Hawaiian Islands.

Subfamily **Daphnellinae**

The distinguishing feature of the daphnellids is the sinus, situated on the suture and shaped like a reversed L. The shells are small to moderately large (3 mm to 75 mm in Hawaii), usually with a cancellate sculpture. The columella is smooth, a parietal callus is present in some, and the lip is produced forward, the edge thin or with a terminal varix. The protoconch is tall, usually sculptured with either a diagonal cancellate pattern or with axial ribbing. There is no operculum. The radula is toxoglossate, the marginal teeth hollow and awl-shaped, the base expanded and the tip constricted.

Twenty daphnellids, found predominantly in shallow water, are discussed; 15 occur at depths of less than 20 m, of which 12 occur in tide pools. *Veprecula* and *Spergo* represent deep-water species.

Daphnella interrupta Pease, 1860. Figs. 117 E; 118 A. Length, 9 mm; diameter, 3 mm. *Shell:* ovate-cylindrical, slender, thin; with fine granular spiral threads, white minutely spotted with brown. *Spire:* protoconch of three and one-half brown whorls, the apical whorls decussate, the abapical whorl with axial riblets; teleoconch of four inflated whorls, the last whorl the longest; suture impressed. *Sculpture:* fine, granular spiral threads, the interspaces of approximately equal diameter. *Aperture:* narrowly ovate, about one-half the length of the spire; outer lip flaring at the base, thin and crenulated by the external sculpture; sinus well-developed, on the line of the advancing suture. *Color:* white splashed with small, irregularly shaped brown spots.

These turrids are common, found under rocks in tide pools subject to heavy surf and in shallow waters on fringing reefs. There is a pelagic veliger larva.

D. interrupta was described from the Hawaiian Islands.

Daphnella ornata (Hinds, 1844). Figs. 117 H; 118 B. (Synonym: *Daphnella maculosa* Pease, 1860.) Length, 7 mm; diameter, 2 mm. *Shell:* ovate-cylindrical, thin; with fine granular spiral threads; white with three spirals of angular brown spots on the last whorl. *Spire:* protoconch of four light brown whorls, the abapical whorl obliquely axially keeled, the others decussate; teleoconch of three inflated whorls, the last whorl the largest; suture impressed. *Sculpture:* fine axial and spiral threads beaded at their junctions, interspaces of greater diameter and microscopically cancellate. *Aperture:*

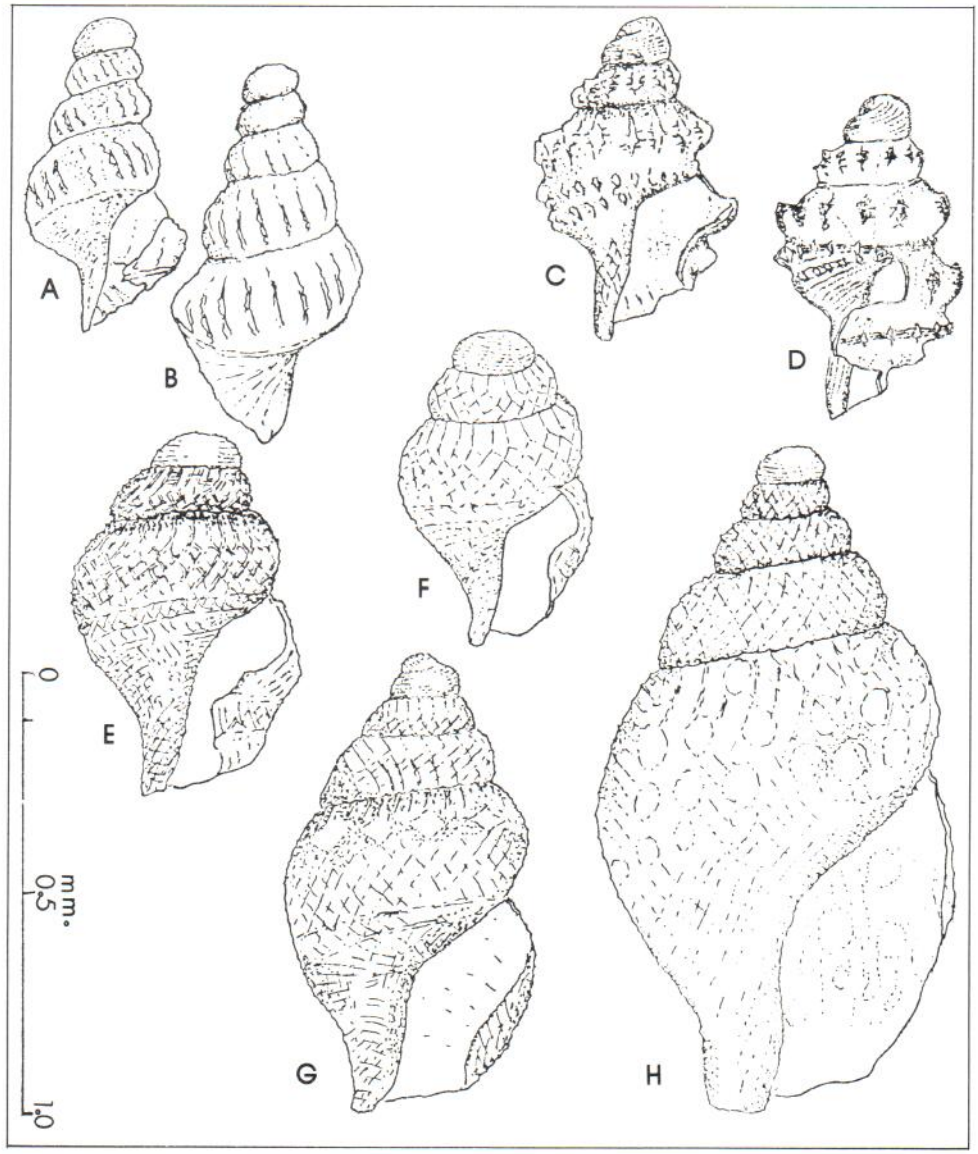


Figure 117.—Presettlement protoconchs of the **Daphnellinae.** A, B. *Veprecula brunnonia*. C, D. *Microdaphne medusa*. E. *Daphnella interrupta*. F. *Kermia melanoxytum*. G. *Kermia brunnea*. H. *Daphnella ornata*. (All from J. B. Taylor, 1975.)

narrowly ovate, about equal in length to the spire; outer lip barely thickened and threaded within. *Color:* white, the last whorl encircled with three spirals of angular brown spots, others with a single row of brown spots.

These turrids are common under rocks in tide pools subject to heavy surf. There is a pelagic veliger larva.

D. ornata is apparently widespread throughout the Pacific, found on the Great Barrier Reef and eastward to Fiji and the Tuamotus (see Hedley, 1922).

Daphnella sandwicensis Pease, 1860. Fig. 118 C. Length, 14 mm; diameter, 5.5 mm. *Shell:* ovate-cylindrical, thin; smooth and glossy; white maculated with brown. *Spire:* protoconch of four red-brown decussate whorls; teleoconch of four inflated whorls, the last whorl the largest; suture impressed. *Sculpture:* smooth and glossy with microscopic wrinkles near the suture and fine spiral striae. *Aperture:* widely ovate, one-half the length of the spire; outer lip thin, arcuate; sinus deep. *Color:* glossy white maculated with brown, the interstices between the brown spots often almost circular.

Shells representing this species are known only from worn specimens collected in beach drift and shells found at depths of 60 m. There is a pelagic veliger larva.

D. sandwicensis was described from the Hawaiian Islands.

Eucyclotoma albomacula Kay, new species. Fig. 118 D. Length, 7.75 mm; diameter, 2 mm (holotype). *Shell:* tall-spired, attenuate; with a sharp spiral keel on each whorl; glossy, chestnut brown with axial streaks of white. *Spire:* protoconch of two and one-half conical whorls; teleoconch of nine somewhat concave whorls turreted by the spiral keels which project from the whorls; suture indistinct, marked by a spiral thread. *Sculpture:* a single sharp, sloping spiral keel on each whorl, the suture on the abapical whorls marked by a fine spiral thread, and the last whorl with a secondary spiral keel and two or three smaller spiral threads; axial sculpture of microscopic striae only, becoming quite prominent on the base of the last whorl. *Aperture:* widely oval, about one-quarter the length of the spire; outer lip thin, scalloped by two projections of the spiral keels; sinus shallow, not well marked. *Color:* glossy, chestnut brown, the suture marked by a linear spiral of white and brown, and with three white axial stripes descending the spire, rather like varices in *Tritonoturris*.

These turrids are rare, found in deep water at depths of 60 m.

Type locality: Kepuhi Point, Oahu, at a depth of 60 m. *Holotype:* Bernice P. Bishop Museum No. 96820. *Paratype:* B. P. Bishop Museum.

This species is distinguished by its single prominent spiral keel on each whorl and the distinctive color pattern. Derivation of name: *alba,* Latin — white; *macula,* Latin — speck or spot. Refers to the white streaks on the otherwise brown shell.

Kermia aniani Kay, new species. Fig. 118 K. Length, 5 mm; diameter, 1.5 mm (holotype). *Shell:* fusiform, slender; with rounded axial ribs crossed by crisp spiral cords; glossy, brown. *Spire:* protoconch of two and one-half light brown, cancellate whorls; teleoconch of four barely convex whorls, the apical whorls somewhat turreted, the last whorl with a sloping shoulder; suture shallow, distinct. *Sculpture:* rounded axial ribs, about nine on the last whorl, extending from suture to base, with narrow, deep interspaces about the same diameter as the ribs; spiral sculpture of rounded cords forming discrete nodules where they cross the ribs and with the interspaces striate. *Aperture:* narrow, less than half the length of the spire; with a conspicuous sinus; outer lip varicose, overrun by the ends of the spiral threads; with four or five denticulations within. *Color:* glossy light to dark brown, sometimes faintly banded with white on the last whorl.

These turrids are common at depths of from 10 to 100 m and shells may be abundant in beach drift along the shores of some beaches.

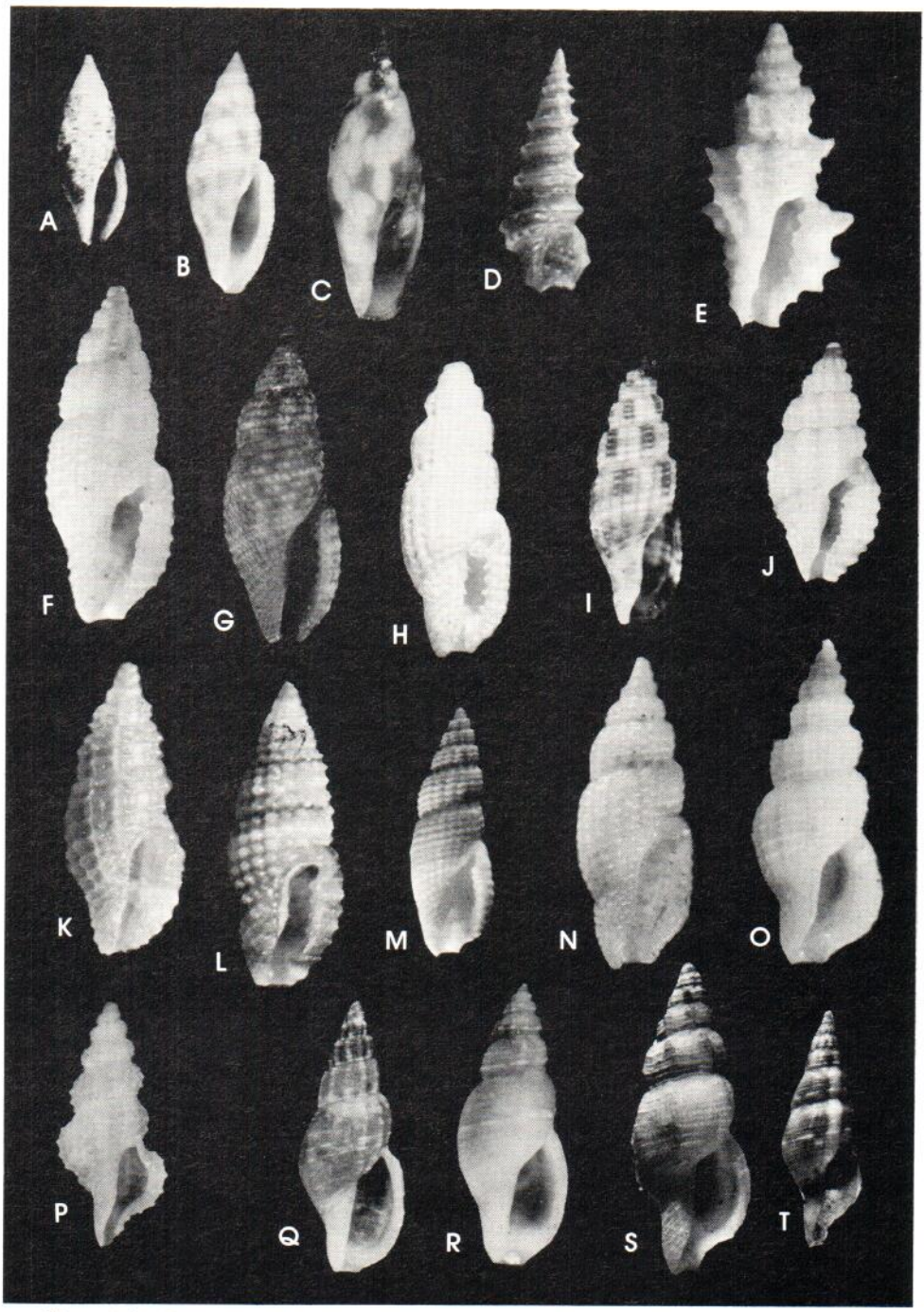


Figure 118.—**Daphnellinae.** A. *Daphnella interrupta*, length 9 mm. B. *D. ornata*, length 7 mm. C. *D. sandwicensis*, length 14 mm. D. *Eucyclotoma albomacula*, length 7.75 mm (holotype). E. *Microdaphne trichodes*, length 3.5 mm. F. *Kermia bifasciata*, length 5 mm. G. *K. brunnea*, length 7 mm. H. *K. cylindrica*, length 3.5 mm. I. *K. daedalea*, length 6 mm. J. *K. melanoxytum*, length 6 mm. K. *K. aniani*, length 5 mm (holotype). L. *K. pumila*, length 5 mm. M. *K. producta*, length 6.5 mm. N. *K. pyrgoidea*, length 6 mm. O. *Pseudodaphnella pulchella*, length 10 mm. P. *Veprecula brunonia*, length 6 mm. Q. *Tritonoturris cumingii*, length 17 mm. R. *T. subrissoides*, length 13 mm. S. *T. robillardi*, length 17 mm. T. *T. paucicostata*, length 10 mm.

Type locality: Nanakuli Beach, Oahu, in beach drift. *Holotype:* Bernice P. Bishop Museum No. 96822. *Paratypes:* Australian Museum; British Museum (Natural History); U. S. National Museum.

The small size, slender form, and brown color distinguish these shells from those of *Kermia iospira* (Hervier, 1895) and *K. episema* (Melvill and Standen, 1896), both described from Lifu, Loyalty Islands. Derivation of name: *aniani,* Hawaiian — mirror, glass, obvious. Refers to the glossy brown shell which stands out among other shells in beach drift and sediments.

Kermia bifasciata (Pease, 1860). Fig. 118 F. Length, 5 mm; diameter, 2 mm. *Shell:* fusiform; with relatively coarse axial ribs spirally belted by finer spiral threads, interspaces cancellate; white. *Spire:* protoconch of three light brown whorls, apical whorls smooth, abapical with fine axial and spiral threads; teleoconch of four somewhat inflated whorls shouldered below the suture; suture shallow and oblique. *Sculpture:* bold axial ribs, the interspaces about equal in diameter crossed by fine spiral keels, the ribs nodular at the intersections. *Aperture:* ovate; outer lip reflected inward and with spiral bands; aperture smooth within. *Color:* white, sometimes faintly spotted with brown.

The habits of these turrids are not known but shells are occasionally found in beach drift.

This species was described from the Hawaiian Islands. Shells of *K. bifasciata* are distinguished from those of *K. producta* by their finer sculpture and the thicker varix on the outer lip.

Kermia brunnea (Pease, 1860). Fig. 118 G. Length, 7 mm; diameter, 2 mm. *Shell:* elongate-fusiform; with fine axial ribs and spiral cords forming beads at the intersections; brown. *Spire:* protoconch of four dark brown decussate whorls, the apical whorl smooth, the two abapical whorls decussate; teleoconch of three or four slender, barely convex whorls separated by an impressed suture. *Sculpture:* slender axial ribs with interspaces of equal diameter crossed by closely set spiral threads forming beads at the junctions; a subsutural band defined by more prominent beading than that on the remainder of the whorl. *Aperture:* narrow; about half the length of the spire; outer lip with a varix and denticulate within; sinus deep, U-shaped. *Color:* dark to red-brown, often mottled with lighter shades, especially lavender.

This is a common shallow-water form, occurring under rocks in tide pools subject to heavy surf.

This species was described from the Hawaiian Islands.

Kermia cylindrica (Pease, 1860). Fig. 118 H. Length, 3.5 mm; diameter, 0.5 mm. *Shell:* fusiform, slender; with coarse axial ribs beaded by spiral threads; white. *Spire:* protoconch of one and one-half bulbous white whorls; teleoconch of three barely convex whorls, the last whorl more than half the length of the spire; suture shallow, wide, not shouldered or angled. *Sculpture:* axial ribs crossed by spiral threads of equal diameter forming beads at their junctions. *Aperture:* narrow, about half the length of the spire; outer lip with a varix and denticulate within. *Color:* white.

These small turrids are uncommon, found occasionally in beach drift on Midway and Oahu.

K. cylindrica was described from the Hawaiian Islands.

Kermia daedalea (Garrett, 1873b). Fig. 118 I. Length, 6 mm; diameter, 2 mm. *Shell:* fusiform, slender; with fine axial ribs reticulated by spiral cords; white tessellated with brown. *Spire:* protoconch of two and one-half dark brown whorls, the apical whorl spirally striate, the abapical whorl decussate; teleoconch of five barely convex whorls, the apical whorls turreted, the last whorl with a subsutural ramp; suture impressed. *Sculpture:* fine axial ribs with interspaces of about the same diameter crossed by spiral cords of slightly lesser diameter than the ribs and forming small beads at the junctions; base with beaded cords. *Aperture:* ovate, about one-third the length of the spire; outer lip denticulate within; sinus well-developed. *Color:* white, spirally banded with axially oriented chestnut blotches, a single row on the apical whorls, two rows on the last whorl.

These shells are uncommon, found in beach drift and to depths of about 10 m.

K. daedalea was described from Fiji.

Kermia melanoxytum (Hervier, 1895). Figs. 117 F; 118 J. Length, 6 mm; diameter, 2 mm. *Shell:* fusiform-ovate, solid; with axial ribs crossed by strong spiral cords; ivory with a spiral of brown thread on the apical whorls and a band of brown basally. *Spire:* protoconch of four brown whorls, the apical whorls smooth, the others decussate; teleoconch of five somewhat angular whorls; suture shallow. *Sculpture:* strong axial ribs, the interspaces subequal and shallow, overridden by spiral cords, and nodular at their intersections with the ribs. *Aperture:* narrow, equal in length to the spire; outer lip with a varix and six denticles within; columella with a single obsolete fold. *Color:* ivory, suture and base of last whorl spirally banded with brown, apical whorls threaded with brown, parietal callus brown.

These turrids are occasionally found under rocks in tide pools subject to heavy surf.

K. melanoxytum was described from Lifu. The shells superficially resemble those of *Lienardia mighelsi* but are distinguished by the daphnellid protoconch, smaller size, and lack of dark banding.

Kermia producta (Pease, 1860). Fig. 118 M. Length, 6.5 mm; diameter, 2.5 mm. *Shell:* fusiform, slender; with fine axial ribs reticulated by spiral cords; cream blotched with white and gray. *Spire:* protoconch of two horn-colored whorls, the apical spirally striate, the abapical decussate; teleoconch of five turreted, lightly convex whorls; suture impressed. *Sculpture:* fine axial ribs with interspaces of lesser diameter crossed by spiral cords of approximately the size of the ribs and forming small beads at the junction; base with beaded cords. *Aperture:* ovate, about one-third the length of the spire; outer lip denticulate within; sinus well developed. *Color:* cream blotched and banded with white and gray.

These turrids are common in shallow water under rocks in tide pools and on fringing reefs.

K. producta was described from the Hawaiian Islands.

Kermia pumila (Mighels, 1845). Fig. 118 L. (Synonym: *Pleurotoma reticulata* Garrett, 1857.) Length, 5 mm; diameter, 2 mm. *Shell:* fusiform, slender, solid; with a granular-reticulated sculpture of axial ribs and spiral threads; mauve and brown. *Spire:* protoconch of two and one-half brown whorls, the apical whorl spirally striate, the others decussate; teleoconch of five slightly convex whorls; suture channeled. *Sculpture:* axial ribs and spiral cords evenly spaced and equal in size, beset with small nodules at their junctions. *Aperture:* narrow, one-third the length of the spire; outer lip with a varix and denticulate within; sinus deep. *Color:* pale violet or mauve spirally banded with light and dark brown. *Animal:* siphon and tentacles tan, foot white.

This is the most common of the shallow-water turrids in Hawaiian waters, found under rocks in tide pools and on fringing reefs.

K. pumila was described from the Hawaiian Islands. Shells resembling this species from Réunion, Okinawa, the Cook Islands, and Fiji are almost uniformly lavender in color and are usually recognized as *K. clandestina* (Deshayes, 1863).

Kermia pyrgoidea (Melvill, 1917). Fig. 118 N. Length, 6 mm; diameter, 2 mm. *Shell:* cylindrical, apex attenuate; with fine axial ribs crossed by spiral threads; white. *Spire:* protoconch of three and one-half convex white whorls; teleoconch of four inflated whorls; suture impressed. *Sculpture:* fine axial ribs, about 25 on the last whorl, crossed by equally fine spiral threads forming small beads at the junctions of the ribs. *Aperture:* narrow, less than half the length of the spire; outer lip varicose, crossed by spiral threads, denticulate within. *Color:* white.

These turrids are uncommon, found in beach drift and to depths of about three m.

K. pyrgoidea was described from the Persian Gulf. The cylindrical form and deeply excavate base are characteristic.

Microdaphne trichodes (Dall, 1919). Fig. 118 E. Length, 3.5 mm; diameter, 2 mm. *Shell:* fusiform, spire tall; spinose; cream blotched with brown on the back of the last whorl. *Spire:* protoconch of four light brown whorls, the apical whorl with punctate spiral striae, the others with axial riblets; teleoconch of three convex whorls; suture distinct. *Sculpture:* spiral sculpture of prominent cords, two to three on the apical whorls, four on the last whorl, the abapical cords and the peripheral cords spinose, the others nodulose; spiral cords mounted over eight to ten slender axial ribs; base with three beaded cords. *Aperture:* narrow, less than half the length of the spire; outer lip with a varix and four strong denticles; sutural sinus distinct, deep. *Color:* cream, usually splashed with dark brown on the back of the last whorl, sometimes also with brown on the penultimate whorl.

These turrids are common in sediments at depths of from 10 to 100 m, and are sometimes locally common in beach drift.

M. trichodes is found both on the west coast of the Americas (from the head of the Gulf of California to Gorgona Island, Colombia, and the Galapagos Islands) (Keen, 1971) and throughout the Indo-West Pacific. It was illustrated from Cocos-Keeling Atoll, Indian Ocean (Maes, 1967).

Pseudodaphnella pulchella (Pease, 1860). Fig. 118 O. Length, 10 mm; diameter, 3.5 mm. *Shell:* fusiform-ovate; with prominent rounded axial ribs crossed by crisp spiral cords; cream, apex rosy. *Spire:* protoconch of two and one-half whorls, the apical oblique and smooth, the others with faint latticelike sculpture; teleoconch of five convex whorls; suture distinct, shouldered. *Sculpture:* strong, rounded axial ribs, about nine on the last whorl, the interspaces shallow, of greater diameter than the ribs; ribs and interspaces crossed by crisp spiral cords, about five major cords on the last whorl with finer intercalary threads between. *Aperture:* subovate, about one-quarter the length of the spire; outer lip with a varix, smooth within; sinus deep, U-shaped, occupying the shoulder slope. *Color:* cream lightly tinted with pink, apex rose-pink.

These shells are rare, found in beach drift.

P. pulchella was described from the Hawaiian Islands.

Tritonoturris cumingii (Powys, 1835). Fig. 118 Q. (Synonym: *Clathurella harpa* Pease, 1860.) Length, 25 mm; diameter, 9 mm. *Shell:* fusiform, ovate; thin; with bold axial ribs; fawn splashed with white. *Spire:* protoconch of four brown, decussate whorls; teleoconch of seven or eight whorls, the last inflated and angular at the suture; suture shallow. *Sculpture:* bold axial ribs with wider, shallower interspaces crossed by weak spiral threads. *Aperture:* ovate; about one-third the length of the spire; outer lip thin. *Color:* pale fawn lineated with white; apical whorls purple-red.

These turrids are found at depths of about 20 m in sand pockets under coral.

T. cumingii was described from Mauritius.

Tritonoturris paucicostata (Pease, 1860). Fig. 118 T. Length, 10 mm; diameter, 3.5 mm. *Shell:* fusiform, slender; light and thin; with remote varices and fine spiral threads; fawn blotched and banded with dark brown. *Spire:* protoconch of four whorls, the apical smooth the next axially striate, and the two abapical whorls with coarse diagonally cancellate sculpture; teleoconch of six inflated whorls; suture deep. *Sculpture:* the three adapical whorls with regularly spaced axial ribs and spiral threads in the interspaces; remaining whorls with remote varices which extend the length of the whorl; spiral sculpture of fine spiral threads crossing the varices and microscopic axial threads between the spirals. *Aperture:* subovate, slightly less than half the length of the spire; sinus moderately developed. *Color:* fawn or white broadly banded with dark brown and with blotches of dark brown and white.

These turrids are rare, found at depths of 100 m and occasionally in beach drift.

T. paucicostata was described from the Hawaiian Islands.

Tritonoturris robillardi (H. Adams, 1869). Fig. 118 S. (Synonym: *Clathurella elegans* Pease, 1860.) Length, 17 mm; diameter, 6 mm. *Shell:* ovate-fusiform; thin; with irregular axial ribs and fine, granular spiral threads; yellow spotted with brown. *Spire:* teleoconch of seven or eight inflated, somewhat shouldered whorls; suture distinct. *Sculpture:* somewhat irregularly spaced axial ribs with wide interspaces granulated by finely beaded spiral threads. *Aperture:* ovate; about one-third the length of the spire; outer lip thin. *Color:* yellow-cream lightly spotted with brown especially on the ribs.

Specimens of *T. robillardi* are occasionally found at depths of about 25 m under dead coral heads.

This species was described from Mauritius; *T. elegans* was described from the Hawaiian Islands.

Tritonoturris subrissoides (Hervier, 1897). Fig. 118 R. Length, 13 mm; diameter, 5 mm. *Shell:* fusiform, ovate; thin; with remote varices and microscopically beaded spiral threads; fawn maculated with white. *Spire:* protoconch of three and one-quarter finely decussated, dark brown whorls; teleoconch of six or seven inflated whorls, the apical whorls turreted, the later whorls with rounded shoulders; suture deep. *Sculpture:* the three apical whorls with regularly latticed sculpture of spiral cords crossing axial ribs, cords and ribs nodular at their junctions; later whorls with remote varices crossed by microscopically beaded spiral threads. *Aperture:* ovate, about half the length of the spire; outer lip thin. *Color:* fawn, spirally banded with a broken white thread, two of the spirals on the last whorl, the others in the suture; maculated and clouded with white.

These turrids are found at depths of 8 to 24 m.

T. subrissoides was described from Lifu, Loyalty Islands.

Veprecula brunonia (Dall, 1924). Fig. 118 P. Length, 6 mm; diameter, 2 mm. *Shell:* tritonlike, thin; with sharp, widely spaced axial ribs crossed by sharp spiral cords forming nodules at the junctions with the ribs; light brown. *Spire:* protoconch of four conical whorls, the apical smooth, the others with arcuate threads; teleoconch of four convex whorls; suture deeply impressed. *Sculpture:* sharp axial ribs, the interspaces of greater diameter, crossed by spiral cords about the same size as the axials, the junctions sharply noduled; interspaces rectangular and spirally striate. *Aperture:* ovate; sinus deep, near the suture. *Color:* light brown.

These turrids have been dredged at depths of 66 to 500 m.

V. brunonia was described from the Hawaiian Islands.

Subfamily **Turriculinae**

This group of turrids, monographed by Powell (1969), is primarily represented by animals found in very deep water in the tropics. The shells are in general narrowly fusiform with a tall spire, long anterior canal, and deep, rounded to a U-shaped sinus. They are, for the most part, of moderate to large size (20 to 100 mm).

Two genera are represented in Hawaii at depths of several hundred meters, *Comitas* with elongately fusiform shells which have foldlike axials and a two-whorled smooth protoconch, and *Thatcheriasyrinx* with small (10 mm), pagodalike, papery thin shells which are coronated or carinated at the periphery. *Comitas oahuensis* Powell, 1969, 17 mm in length, is known from three shells dredged by the *Albatross* at depths of from about 500 to 600 m. *C. kamakurana* (Pilsbry, 1895) is doubtfully recorded from the Hawaiian Islands; a shell described as *Surcula laysanica* Dall, 1919, from Laysan, is a specimen of the Pilsbry species but Powell (1969) questions its Hawaiian locale. A single specimen of a species of *Thatcheriasyrinx,* 4 mm in length (Fig. 115 N), was dredged from a depth of 700 m off Lanai. This record extends the range of

the genus previously known from the Gulf of Oman, the Philippines, and Japan (Powell, 1966), to the mid-Pacific.

Additional Records

Of the 10 species referred by Mighels (1845) to *Pleurotoma*, only four are identifiable with certainty from the sketchy, unillustrated descriptions. Three, *Pleurotoma acuminata (= Clavus)*, *P. pumila (= Kermia)*, and *P. rugosa (= Lienardia mighelsi)* are turrids, but the fourth, *P. todilla (= Thala)* is a mitrid. The remaining six species, *P. circumsecta*, *P. crassilabrum*, *P. micans*, *P. obnubila*, *P. coronata*, and *P. sinuosa* are not identifiable.

W. H. Pease described 23 species in turrid genera in 1860-61 (Kay, 1965). Two, *Clathurella fuscomaculata (= Caducifer decapitata)* and *Cythara varia (= Seminella virginea)*, are referable to the Buccinidae and Columbellidae respectively. Two, *Clathurella cylindrica* and *C. buccinoides*, have not been seen in recent collections since Pease's descriptions.

Five deep-water species were described by Dall (1895) from the dredging activities of the *Albatross*, and are known only from the type material. Three are daphnellids, *Pleurotomella climacella (= Bathyclionella fide* Powell, 1966), *Spergo daphnelloides*, and *S. glandiniformis*. Two, *Mangelia (Pleurotomella) gypsina* and *M. (P.) hawaiiana* remain to be assigned in a modern arrangement of the turrids.

Pleurotoma amicta E. Smith, 1877, was erroneously recorded from the Hawaiian Islands (Powell, 1964) but Kosuge (1969) records it as a Pleistocene fossil from Oahu.

Family **Conidae**

The cones are among the most easily recognized gastropods with shells which are broad apically and which taper to a narrow base. The aperture is long, narrow, and usually of almost uniform width; the outer lip is thin and the operculum clawlike, much smaller than the aperture. Ornamentation is limited to tubercles on the spire and faint granules and spiral striae on the body whorl, but most of the tropical species are brightly and elaborately colored.

The cones are carnivorous, equipped with a sac of loosely attached, sharp, sometimes barbed, hollow teeth, each of which is connected to a venom gland (Fig. 120). In obtaining its prey the animal extrudes one of these teeth from its proboscis and impales its victim, a fish, worm, or other mollusk, which is paralyzed by venom from the gland and swallowed whole.

The "stings" of certain cones are notorious for causing fatalities, paralysis, and painful wounds among humans. *Conus textile* which has caused fatalities elsewhere in the Indo-West Pacific occurs in Hawaiian waters, but no fatalities have been reported in Hawaii. Three Hawaiian cones, *C. quercinus*, *C. obscurus*, and *C. sponsalis* are known to have caused painful wounds in the Hawaiian Islands, however, and *C. catus* is recorded as having done so elsewhere (Kohn, 1963).

The sexes are separate and fertilization is internal. The egg capsules are "like a flattened pouch or flask" (Knudsen, 1950). They are white or straw-colored, deposited

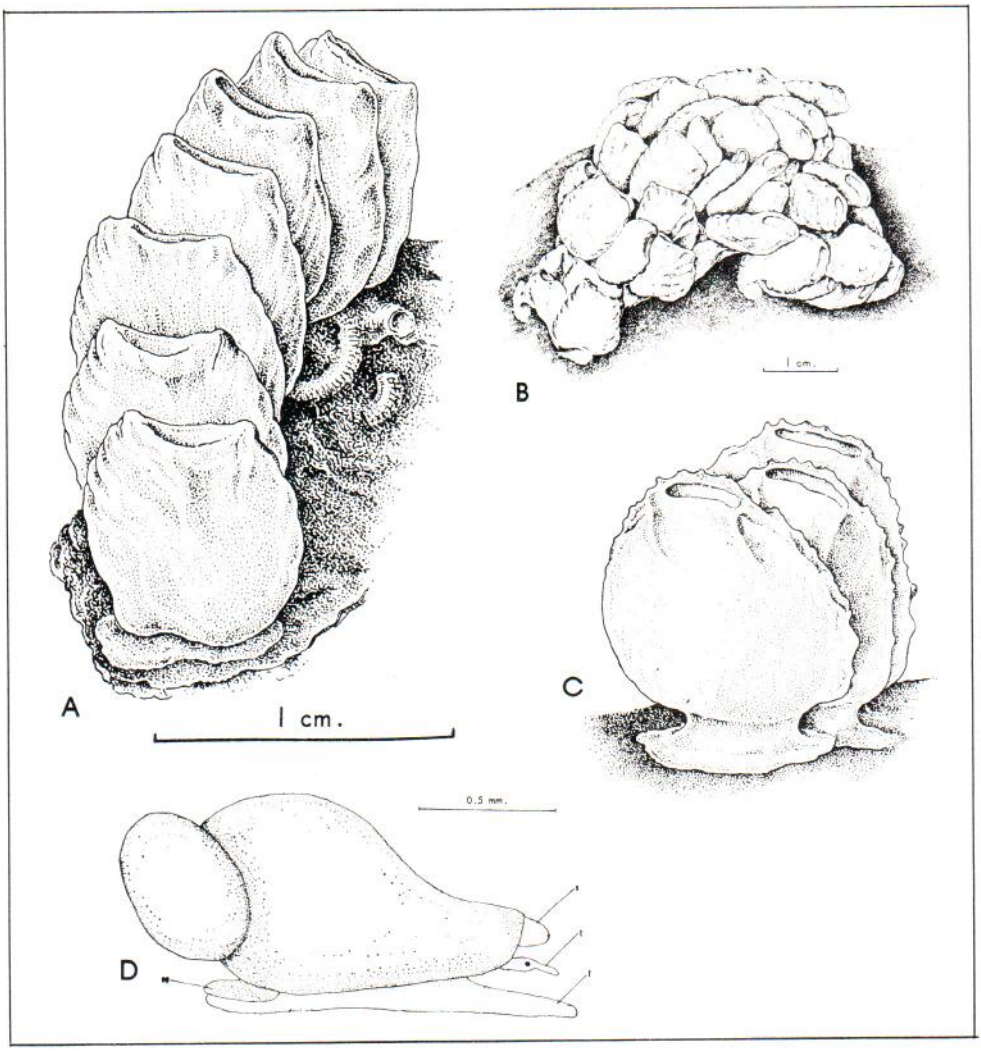


Figure 119.—**Conidae.** A. Egg mass of *Conus abbreviatus*. B. Egg mass of *C. pennaceus*. C. Egg mass of *C. lividus*. D. Veliconch of *C. pennaceus*. (From Kohn, 1961.)

in clusters consisting of short rows of a few clusters each. In Hawaii the number of capsules per cluster ranges from one to sixty-eight and the number of eggs from 80 to about 1,000. In most species each capsule is attached to the substratum by a basal plate (Fig. 119). There is a narrow, short stalk above which is the capsule proper. The capsule wall is thin and nonrigid, and usually bears ridges on the flat surface. The lateral edges are convex and there is a preformed exit window covered with a hyaline membrane on the uppermost part. Kohn (1959a) indicates that there is some degree of interspecific variation and it is not usually possible to determine the species to which an egg mass belongs in the absence of a parent.

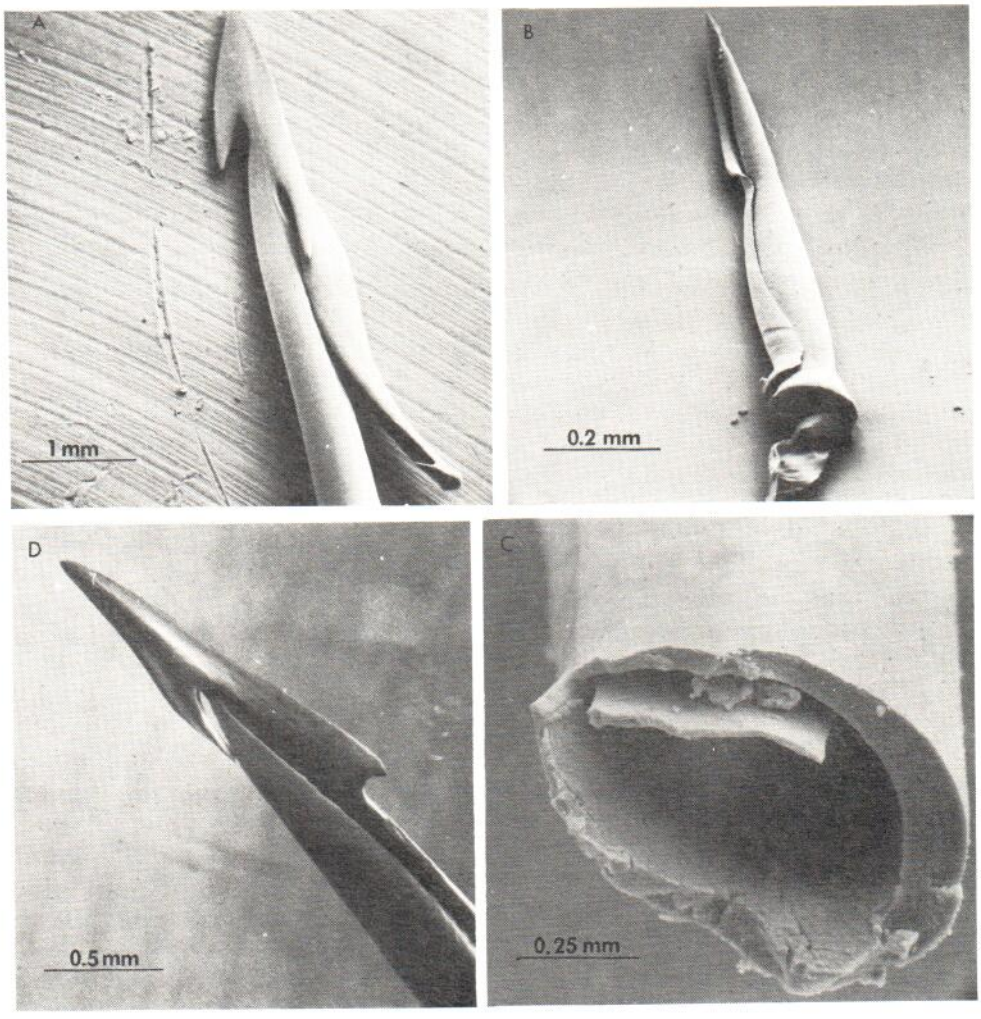


Figure 120.—The radulae of *Conus*. A. *Conus striatus*, tooth length 12 mm; mode of feeding piscivorous. B. *C. sponsalis*, tooth length 0.7 mm, mode of feeding vermivorous. C. *C. textile*, tooth length 14 mm, mode of feeding molluscivorous. D. *C. pennaceus*, cross section of 5 mm tooth, mode of feeding molluscivorous. (Photos by M. James.)

Most species of cones in Hawaii have a four-lobed veliger larva. J. B. Taylor (1975) described the veligers of 20 species from the plankton of Kaneohe Bay, Oahu.

Cones are among the most conspicuous gastropods of reefs and benches that fringe the shorelines, as well as of deeper waters offshore in the Hawaiian Islands. Of the 25 species which have been found on reefs and benches, six, *Conus sponsalis*, *C. abbreviatus*, *C. ebraeus*, *C. chaldaeus*, *C. rattus*, and *C. catus*, are dominant on marine benches, and two, *C. flavidus* and *C. lividus*, are dominant on subtidal reefs (Kohn, 1959a). In dredge hauls off the leeward coast of Oahu at depths of 20 to 200 m, *C. litoglyphus* and *C. pulicarius* comprise eight and ten percent, respectively, of the large gastropods collected.

Conus abbreviatus Reeve, 1843. Fig. 121 A. (Synonym: *Conus miliaris* var. *abbreviatus* Reeve, Tinker, 1952.) Length, 33 mm; diameter, 21 mm. *Shell:* shoulder coronate; sturdy; blue-gray with pale spiral bands and rows of distantly spaced minute brown dots. *Spire:* depressed to moderately elevated. *Sculpture:* finely spirally striate, the striae as raised ridges near the base and widely spaced on the last whorl; shoulder and spire with distinct, well-spaced tubercles. *Aperture:* narrow, flaring slightly toward the base; base attenuate. *Color:* blue-gray, spirally banded with pale flesh and with widely spaced spiral rows of brown dots; aperture white, sometimes blotched or banded with purple-brown. Periostracum thin, yellow. *Animal:* foot pale brown; siphon pale brown, tinged with pink (Kohn, 1959b).

C. abbreviatus is common on benches and on sandy substrates of reef platforms; a few specimens have been dredged to depths of 60 m. These cones feed exclusively on polychaete worms (Kohn, 1959a). There is a four-lobed veliger larva and metamorphosis occurs when four and one-quarter whorls are complete, at a columellar length of about 1120 μm (J. B. Taylor, 1975). Length of life in the plankton is estimated as about five to seven weeks (J. B. Taylor, 1975).

Although here considered endemic to the Hawaiian Islands, *C. abbreviatus* has also been recorded from the Marshall and Line Islands (Kohn and Weaver, 1962), but does not appear to be represented by breeding populations except in Hawaii. Some malacologists consider *C. abbreviatus* a subspecies of *C. miliaris* Hwass in Bruguière, 1792.

Conus acutangulus Lamarck, 1810. Fig. 121 B. Length, 21 mm; diameter, 10 mm. *Shell:* conic-elongate; spire elevated and turreted, granular; white with interrupted broad brown spiral bands on either side of the center and with spiral rows of brown dots. *Spire:* elevated, turreted, apex sharp. *Sculpture:* spire sculpture of nodulose spirals, the interspaces with <-shaped axial threads interrupted centrally by spiral striae; last whorl with punctate spiral grooves. *Aperture:* narrow, outer lip protracted. *Color:* white, the last whorl with yellow-brown axial splashes and spirals of distantly spaced yellow-brown spots on the ridges. Periostracum thin, translucent, smooth and brown. *Animal:* anterior portion of sole of foot buff, posterior half light purple-brown; siphon buff at the tip and darker tan proximally; rostrum buff (Kohn and Weaver, 1962).

Shells are moderately common at depths of 20 to 60 m.

C. acutangulus also occurs in the Philippines and Fiji (Cernohorsky, 1964b).

Conus bullatus Linnaeus, 1758. Fig. 121 M. Length, 50 mm; diameter, 21 mm. *Shell:* oblong-ovate; thick, glossy; white or pale pink clouded with subtrigonal orange-brown marks. *Spire:* moderately elevated, canaliculate, apex projecting. *Sculpture:* smooth, with impressed spiral striae basally. *Color:* white or pale pink clouded with orange-brown subtrigonal markings often fused and forming three broad spiral bands separated by areas of sparser, irregularly placed similar markings; spire with irregular orange-brown splashes and pink or pink-white; aperture pink-orange. Periostracum thin.

This cone is rarely found, with only five or six shells recorded from depths of 20 to 42 m.

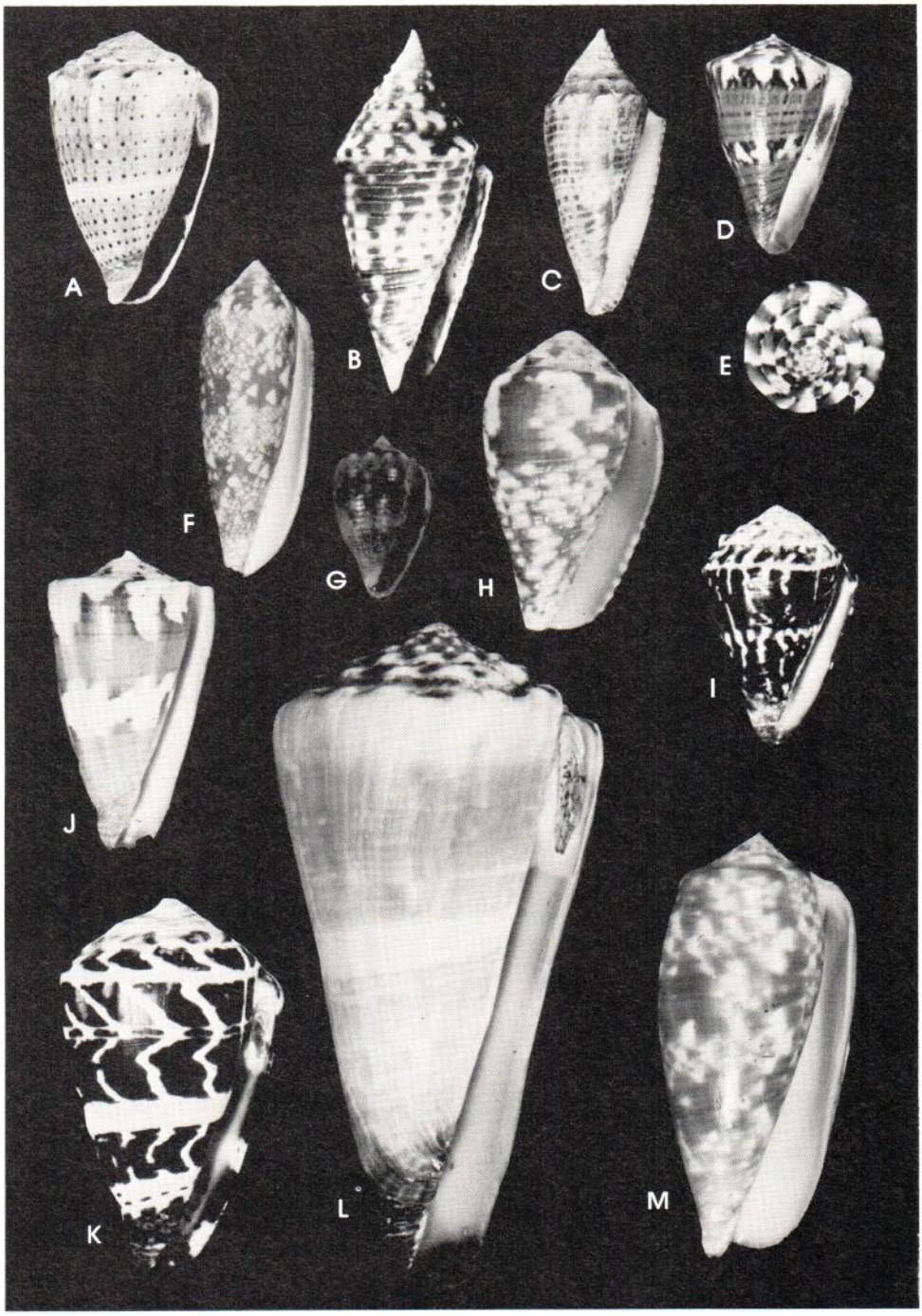


Figure 121.—**Conidae.** A. *Conus abbreviatus*, length 30 mm. B. *C. acutangulus*, length 20 mm. C. *C. eugrammatus*, length 20 mm. D, E. *C. capitaneus*, length 30 mm. F. *C. auricomus*, length 34 mm. G. *C. coronatus*, length 22 mm. H. *C. catus*, length 20 mm. I. *C. chaldaeus*, length 30 mm. J. *C. circumactus*, length 30 mm. K. *C. ebraeus*, length 42 mm. L. *C. distans*, length 115 mm. M. *C. bullatus*, length 50 mm.

C. bullatus may be limited in its distribution to the Pacific Ocean, where it also occurs in Fiji (Cernohorsky, 1964b).

Conus capitaneus Linnaeus, 1758. Fig. 121 D, E. Length, 31 mm; diameter, 21 mm. *Shell:* shoulder smooth; last whorl thick and sturdy; cream to yellow-brown with spiral white bands blotched with brown at the shoulder and medially. *Spire:* low, concave, spirally striate. *Sculpture:* smooth, with impressed striae basally. *Aperture:* wide. *Color:* cream to yellow-brown with two spiral white bands, the shoulder band with axial streaks of brown and the medial band blotched with brown, occasionally with an interrupted dark band encircling the last whorl; base stained with dark brown; spire flecked with dark brown and white; aperture violet.

This is a rare species, found at depths of 20 m.

C. capitaneus has been recorded at several localities in the Indo-West Pacific; Cernohorsky (1964b) records it from Fiji "under dead coral, in shallow water and deeper."

Conus catus Hwass in Bruguière, 1792. Fig. 121 H. (Synonym: *Conus purus* Pease, 1863c.) Length, 32 mm; diameter, 20 mm. *Shell:* shoulder smooth; last whorl inflated, spirally striate; brown irregularly blotched with white. *Spire:* obtuse, deeply striate. *Sculpture:* distinct, sharply incised spiral striae which become ridged and granulose basally. *Aperture:* rather broad, the sides almost parallel. *Color:* brown with irregular white flecks and splotches; aperture white with a brown margin. Periostracum, thin, yellow, translucent. *Animal:* foot buff, mottled with brown.

C. catus is a shallow-water species found intertidally on benches and rocky shores as well as subtidally; these cones feed on fishes such as gobies and blennies (Kohn, 1959a). Pleistocene fossils are known from Oahu (Ostergaard, 1928).

This species is distributed throughout the Indo-West Pacific.

Conus chaldaeus (Röding, 1798). Fig. 121 I. (Synonym: *Conus vermiculatus* Lamarck, Garrett, 1878.) Length, 33 mm; diameter, 19 mm. *Shell:* shoulder coronate; last whorl thick and sturdy; spirally striate; black with an interrupted spiral of white at the shoulder and centrally and with irregular axial streaks of white. *Spire:* moderately elevated. *Sculpture:* spire spirally striate; shoulder and spire coronated with blunt tubercles; last whorl with spiral striae becoming granular apically and basally. *Aperture:* narrow, outer lip flaring at the base. *Color:* mostly black, with irregular interrupted axial streaks of white at the shoulder and centrally on the last whorl; aperture blue-white, the external color pattern visible through the outer lip. Periostracum thin, yellow. *Animal:* foot black with a broad central longitudinal tan stripe on the sole; siphon and rostrum black tipped with red (Kohn, 1959b).

C. chaldaeus occurs most commonly near the outer edge of benches where it feeds exclusively on polychaetes (Kohn, 1959a). Pleistocene fossils are known from Oahu (Ostergaard, 1928).

This species occurs throughout the Indo-West Pacific and has been recorded from Clipperton Island (Hertlein, 1937 as *C. ebraeus vermiculatus*).

Conus circumactus Iredale, 1929b. Fig. 121 J. (Synonym: *Conus hammatus* Bartsch and Rehder, 1943.) Length, 30 mm; diameter, 16 mm. *Shell:* shoulder

smooth; last whorl solid, finely spirally striate; spirally banded with yellow-brown centrally and basally, with white centrally and at the shoulder. *Spire:* low, acuminate. *Sculpture:* spirally striate basally, often finely granular. *Aperture:* narrow, outer lip flaring at the base. *Color:* spire white, tesselated with brown; last whorl yellow-brown spirally banded with pink or white at the shoulder and centrally.

This species occurs at depths of from 16 to 120 m; the holotype of *C. hammatus* was dredged from 600 m.

C. circumactus is apparently limited in its distribution to the Pacific Ocean.

Conus coronatus Gmelin, 1791. Fig. 121 G. Length, 22 mm; diameter, 14 mm. *Shell:* shoulder coronate; bulbous, solid; white freckled with minute dark spots. *Spire:* elevated, nodulose. *Sculpture:* fine spiral striae encircling the last whorl and becoming granular at the base. *Aperture:* wide. *Color:* white or cream with minute brown or black spots freckling the last whorl and occasionally coalescing as blotches; aperture purple-gray with a white median band and edge; spire flecked with brown.

This cone is rarely found in Hawaiian waters, but specimens have been recorded from sand at depths of less than a meter (Weaver, 1963c).

C. coronatus is a well-known species throughout the Indo-West Pacific; it is recorded as a common shallow-water species in Fiji (Cernohorsky, 1964b).

Conus distans Hwass in Bruguière, 1792. Fig. 121 L. Length, 125 mm; diameter, 45 mm. *Shell:* shoulder coronate; last whorl solid, elongate, slightly concave in profile; ocher banded with white at the center, base with a purple-brown stain. *Spire:* short convex. *Sculpture:* shoulder and spire coronated with obtuse rounded tubercles (these may occasionally be obsolete); last whorl smooth or with obsolete axial striae. *Aperture:* narrow, sides parallel. *Color:* ocher banded with white or pale blue, tubercles of spire white, depressed areas brown; base purple-brown; aperture violet or white, darker violet in juveniles. Periostracum thick, olive-green or brown, with tufted spiral ridges on the body whorl. *Animal:* foot brown; siphon light tan, mottled with brown; rostrum dark brown tipped with yellow; tentacles light brown.

These cones are common in shallow water, found chiefly on the outer areas of reef platforms and at depths of 2 m or more where there is some surf action; the shells are usually seen exposed on the substrate. *C. distans* feeds on polychaetes (Kohn, 1959a).

This species is well-known throughout the Indo-West Pacific.

Conus ebraeus Linnaeus, 1758. Fig. 121 K. Length, 42 mm; diameter, 30 mm. *Shell:* shoulder coronate; shell solid; white with three rows of large, angular black spots. *Spire:* moderately elevated. *Sculpture:* last whorl smooth, encircled with raised ridges near the base. *Aperture:* narrow, outer lip flaring basally. *Color:* white, usually with three rows of angular, black spots, and additional rows at the base and shoulder; occasionally with a spiral row of black dashes; aperture with dark bands corresponding to the exterior markings. Periostracum thin, yellow. *Animal:* foot black with a broad, longitudinal central buff stripe on the sole; siphon and rostrum black tipped with a narrow red margin.

C. ebraeus is one of the most abundant species of *Conus* in the Hawaiian Islands. It is the dominant cone on benches and also occurs on reef platforms. These cones

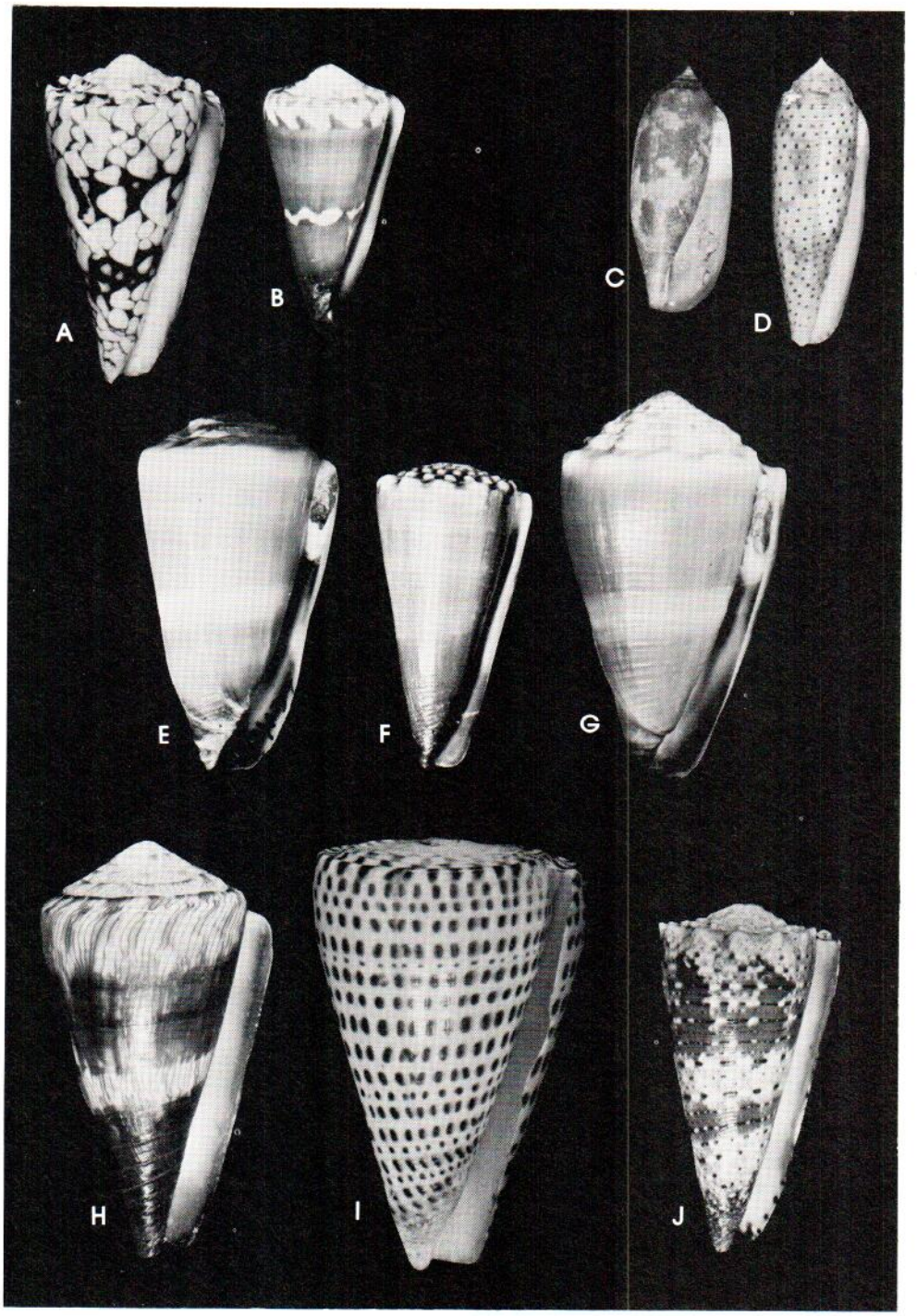


Figure 122.—**Conidae.** A. *Conus marmoreus*, length 60 mm. B. *C. litoglyphus*, length 40 mm. C. *C. obscurus*, length 27 mm. D. *C. nussatella*, length 40 mm. E. *C. flavidus*, length 40 mm. F. *C. moreleti*, length 20 mm. G. *C. lividus*, length 36 mm. H. *C. miles*, length 40 mm. I. *C. leopardus*, length 140 mm. J. *C. imperialis*, length 60 mm.

feed on polychaetes (Kohn, 1959a). Pleistocene fossils are known from Oahu (Ostergaard, 1928).

This species is common throughout the Indo-West Pacific but it attains a greater size in the Hawaiian Islands than elsewhere in its range (Kohn, 1959b). In the Pacific *C. ebraeus* occurs as far east as Clipperton Island (Hertlein, 1937).

Conus eugrammatus Bartsch and Rehder, 1943. Fig. 121 C. Length, 22 mm; diameter, 10 mm. *Shell:* conic-elongate; spire elevated and turreted, comprising more than one-third of the total shell length; spirally striate; white with splashes of subquadrate brown spots and spirals of smaller brown dots. *Spire:* elevated, turreted, slightly concave, shoulder angular. *Sculpture:* spire sculpture of keeled spirals which may be obsoletely granular and slender, curved axial threads; last whorl with punctate spiral grooves. *Aperture:* narrow, outer lip protracted. *Color:* white with strong yellow-brown subquadrate spots mainly confined to the striae. Periostracum very thin, yellow-brown, translucent.

C. eugrammatus is a deep-water species, known from only a few specimens. The type material was dredged by the *Albatross* at depths of 106 to 422 m; other specimens have been dredged at depths from 56 to 120 m.

C. eugrammatus was described from the Hawaiian Islands.

Conus flavidus Lamarck, 1810. Fig. 122 E. (Synonyms: *Conus neglectus* Pease, 1861a, non *neglectus* A. Adams, 1853; *Lithoconus peasei* Brazier, 1877.) Length, 42 mm; diameter, 26 mm. *Shell:* shoulder smooth, angular; last whorl thick and heavy; olivaceous, spirally banded with white, base purple. *Spire:* low, almost flat. *Aperture:* narrow, outer lip slightly concave. *Color:* variable — olivaceous or yellow-brown banded with white and/or blue-white at the shoulder and below the middle of the last whorl; base stained with dark violet; aperture violet with a light central band and yellow margin. Periostracum gray, transversely ridged in young specimens, smooth in older individuals. *Animal:* upper surface of foot red-brown mottled with brown; remainder of foot and rostrum light yellow-brown mottled with darker; siphon, distally banded with black and yellow, proximally yellow mottled with black; tentacles white to yellow.

These cones are common, occurring on reefs where they feed chiefly on polychaetes (Kohn, 1959a). Pleistocene fossils have been reported on Oahu (Ostergaard, 1928; Kohn, 1959b) and on Molokai (Ostergaard, 1939).

This is a well-known species throughout the Indo-West Pacific.

Conus imperialis Linnaeus, 1758. Fig. 122 J. Length, 60 mm; diameter, 31 mm. *Shell:* shoulder sharply coronate; sturdy, last whorl elongate; white with wide spiral bands of yellow-brown and linear brown dashes. *Spire:* low, almost depressed. *Sculpture:* basally striate; shoulder and spire with strong, sharply tipped tubercles. *Aperture:* narrow, flaring at the base. *Color:* white, with two wide spiral bands of yellow-brown, the apical usually broader, and irregularly spaced spirals of brown linear dashes; base and aperture dark purple. Periostracum thin, yellow; the shell often covered with coralline algae. *Animal:* exposed soft parts red speckled with black.

These cones are rather uncommon on reef platforms, and have also been recorded to depths of at least 60 m. They feed exclusively on polychaete worms (Kohn, 1959a). This species is known from Pleistocene fossils on Oahu (Ostergaard, 1928).

C. imperialis occurs throughout the Indo-West Pacific.

Conus leopardus (Röding, 1798). Fig. 122 I. (Synonyms: *Conus millepunctatus* Garrett, 1878; *C. literatus* [sic] *millepunctatus* Lamarck, Edmondson, 1933; *C. literatus* Linnaeus, Tinker, 1952.) Length, 140 mm; diameter, 80 mm. *Shell:* shoulder smooth; massive and heavy; white with 18 or more spirals of axially rectangular blue-brown or black spots. *Spire:* depressed; spirally canaliculate. *Sculpture:* obscure axial striae on last whorl. *Aperture:* narrow, flaring basally. *Color:* cream white with many (18 or more) spiral rows of oblong blue-brown to black spots which are often more pronounced in smaller individuals; aperture white or pale orange. Periostracum olive-brown, very thick and opaque. *Animal:* exposed soft parts yellow-white mottled with brown.

C. leopardus is occasionally found on reef platforms, but occurs more commonly at depths of 2 m or more, usually near old coral heads. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

C. leopardus occurs throughout the Indo-West Pacific. It is reported as common "in patches of sand, often exposed, in shallow water" in Fiji (Cernohorsky, 1964b).

Conus litoglyphus Hwass in Bruguière, 1792. Fig. 122 B. (Synonym: *Conus ermineus* Born, Tinker, 1958.) Length, 40 mm; diameter, 21 mm. *Shell:* shoulder smooth; last whorl elongate; yellow-brown, spirally vacuolated with white at the shoulder and centrally, spire maculated brown and white. *Spire:* depressed; apex projecting. *Sculpture:* last whorl smooth; base with coarse, often granular spiral ridges. *Aperture:* very narrow, sides parallel. *Color:* variable — yellow, red-brown, or chestnut, often darker at the base, spirally banded at the center and shoulder with rows of white blotches; spire maculated brown and white; aperture white. Periostracum thin, light brown, ridged. *Animal:* sole and dorsal margin of the foot olive-green mottled with black, remainder of foot olive-green; siphon, rostrum, and tentacles black.

C. litoglyphus is found only rarely on Hawaiian reefs but is common at depths of 10 to 60 m.

This species occurs throughout the Indo-West Pacific.

Conus lividus Hwass in Bruguière, 1792. Fig. 122 G. (Synonym: *Conus sanguinolentus* Quoy and Gaimard, Greene, 1953.) Length, 36 mm; diameter, 20 mm. *Shell:* shoulder coronated, last whorl broad and solid; drab or yellow-brown with a central spiral band of white, aperture violet. *Spire:* moderately elevated. *Sculpture:* spire finely striate; shoulder and spire coronated with large tubercles; last whorl with widely spaced spirals of elevated striae becoming granular basally. *Aperture:* narrow, sides parallel. *Color:* drab or yellow-brown with a central spiral band of white, tubercles white; aperture violet with a pale transverse band, margin of outer lip yellow. Periostracum thick and opaque. *Animal:* foot, rostrum, and siphon black, finely mottled with more or less red.

C. lividus is one of the two most abundant species of *Conus* on reef platforms,

occurring with *C. flavidus*. These cones feed on polychaetes and on the enteropneust *Ptychodera flava* (Kohn, 1959a).

This species is well-known throughout the Indo-West Pacific.

Conus marmoreus Linnaeus, 1758. Fig. 122 A. (Synonym: *Conus bandanus* Hwass, Greene, 1953.) Length, 60 mm; diameter, 38 mm. *Shell:* shoulder sharply coronate; last whorl sturdy, maximum diameter slightly anterior to that of the shoulder; with triangular pale flesh markings interrupted by dark brown. *Spire:* low, depressed. *Sculpture:* spire sharply tuberculate; shoulder coronated by strong tubercles; last whorl obsoletely striate. *Aperture:* narrow with almost parallel margins; outer lip flaring slightly basally. *Color:* triangular pale flesh markings interrupted by two rather irregular bands of dark brown on the last whorl; aperture white or pale pink. Periostracum thin, yellow. *Animal:* foot pale tan; siphon banded proximally from the tip with white, dark brown, and a half band of tan; rostrum cream mottled with brown; tentacles cream, tipped with brown (Kohn and Weaver, 1962).

C. marmoreus is rather uncommon on reefs, and specimens have been dredged from depths to 90 m. These cones apparently feed entirely on other species of *Conus;* animals have been observed feeding on *C. abbreviatus* and *C. lividus* (Kohn, 1959a), and on *C. litoglyphus* and *C. miles* (Harrison, pers. comm.).

Kohn (1959a) suggests that because of the distinctive color markings, the Hawaiian form may be considered a subspecies, *C. marmoreus bandanus* Hwass in Bruguière, 1792. *C. marmoreus* is found throughout the Indo-West Pacific; Cernohorsky (1964b) records it as a common shallow-water species in Fiji.

Conus miles Linnaeus, 1758. Fig. 122 H. Length, 39 mm; diameter, 24 mm. *Shell:* shoulder smooth; last whorl solid; white with a broad spiral band of brown centrally and at the base and with hairline axial lineations of lighter brown. *Spire:* moderately elevated, straight or convex. *Sculpture:* last whorl smooth except for granular striae basally; shoulder may be obsoletely coronate; spire obsoletely tuberculate or plicate. *Aperture:* narrow, sides parallel. *Color:* white with a band of dark brown centrally and another basally, the bands often divided into lighter and darker portions, and with hairline axial streaks of lighter brown emanating from the central band; aperture with the external color showing through. Periostracum green-brown with spiral rows of tufted ridges on the body whorl. *Animal:* exposed parts green-black.

This species is uncommon in Hawaiian waters; occasional specimens are found on reefs and benches and at depths to 28 m. *C. miles* feeds exclusively on polychaetes (Kohn, 1959a).

C. miles is distributed throughout the Indo-West Pacific. It is common under coral on the reef substrate in shallow water in Fiji (Cernohorsky, 1964b).

Conus moreleti Crosse, 1858. Fig. 122 F. (Synonym: *Conus oblitus* Reeve, Tinker, 1952.) Length, 22 mm; diameter, 11 mm. *Shell:* shoulder coronate; last whorl narrow, elongate, smooth except for basal striae; yellow-olive or ocher, spire tubercles white. *Spire:* low, barely convex. *Sculpture:* spire finely striate; shoulder and spire coronate with large, blunt tubercles; last whorl smooth, with raised, obsoletely knobbed striae basally. *Aperture:* very narrow, sides parallel. *Color:* yellow-olive or ocher,

darker at the base, with lighter transverse bands at the shoulder and the middle; aperture violet, outer lip yellow; spire tubercles white. Periostracum yellow-brown, thin, forming tufts on the tubercles. *Animal:* upper portion of foot brown-red, mottled with brown and tipped with vermilion; remainder of foot and rostrum yellow-brown mottled with darker; tip of siphon vermilion and yellow, followed proximally by black and yellow or vermilion bands, remainder of siphon yellow mottled with black; tentacles white or pale yellow (Kohn and Weaver, 1962).

These cones are common at depths of 6 to 15 m where they are found in dead heads of the coral *Porites*.

C. moreleti occurs throughout the Indo-West Pacific.

Conus nussatella Linnaeus, 1758. Fig. 122 D. Length, 40 mm; diameter, 14 mm. *Shell:* cylindrical; shoulder smooth, sloping; with spirals of granular striae; yellow-white clouded with orange-brown and with spirals of orange-brown spots. *Spire:* high, convex, apex sharp, shoulder rounded. *Sculpture:* last whorl spirally striate with close-set, granular striae. *Aperture:* narrow, flaring basally. *Color:* yellow-white, clouded irregularly with orange-brown or light purple-brown axial splotches; with numerous spiral rows of minute dark orange-brown spots. Periostracum thin, yellow, translucent.

C. nussatella is rather rare in the Hawaiian Islands, and specimens are only occasionally collected on reefs or dredged. The animals are molluscivorous, feeding on cones and *Morula* spp. (Calabrese, 1971). Pleistocene fossils have been collected on Oahu by Ostergaard (1928) and Kohn (1959b).

C. nussatella is distributed throughout the Indo-West Pacific.

Conus obscurus Sowerby, 1833. Fig. 122 C. (Synonym: *Conus halitropus* Bartsch and Rehder, 1943.) Length, 27 mm; diameter, 10 mm. *Shell:* elongate-ovate; thin; smooth except for spiral grooves basally; irregularly blotched with light brown and mauve. *Spire:* moderately elevated; apex pointed. *Sculpture:* spiral grooves basally; spire striate. *Aperture:* rather broad, flaring basally. *Color:* irregularly shaped and distributed blotches and dots of light brown; the lighter areas separating them mauve or lilac. Periostracum very thin, translucent. *Animal:* sole of foot flesh tinged with pale brown; dorsum of foot, siphon, and rostrum flesh tinged with darker; tentacles white (Kohn and Weaver, 1962).

Specimens of *C. obscurus* are rare in shallow water, but are more often found in coral heads at depths to 40 m. These mollusks feed on fish (Kohn, 1959a). There is a four-lobed veliger larva and metamorphosis occurs when about five whorls are complete, at a length of 2100 μm (J. B. Taylor, 1975).

This species may be limited in its distribution to the Pacific Ocean; Cernohorsky (1964b) records it as rare in Fiji, "under coral, on reef substrate, in deeper water."

Conus pennaceus Born, 1780. Fig. 123 A, B. (Synonyms: *Conus racemosus* Sowerby, 1873; *C. auratus,* Hwass, Ostergaard, 1928; *C. episcopus* Hwass, Edmondson, 1933; *C. omaria* Hwass, Edmondson, 1946; *C. elisae* Kiener, 1845, Kohn, 1959b.) Length, 60 mm; diameter, 35 mm. *Shell:* shoulder smooth, rounded; last whorl ventricose; red-brown with large, subtrigonal white blotches. *Spire:* variable — depressed to moderately elevated, concave to slightly convex. *Sculpture:* spire obso-

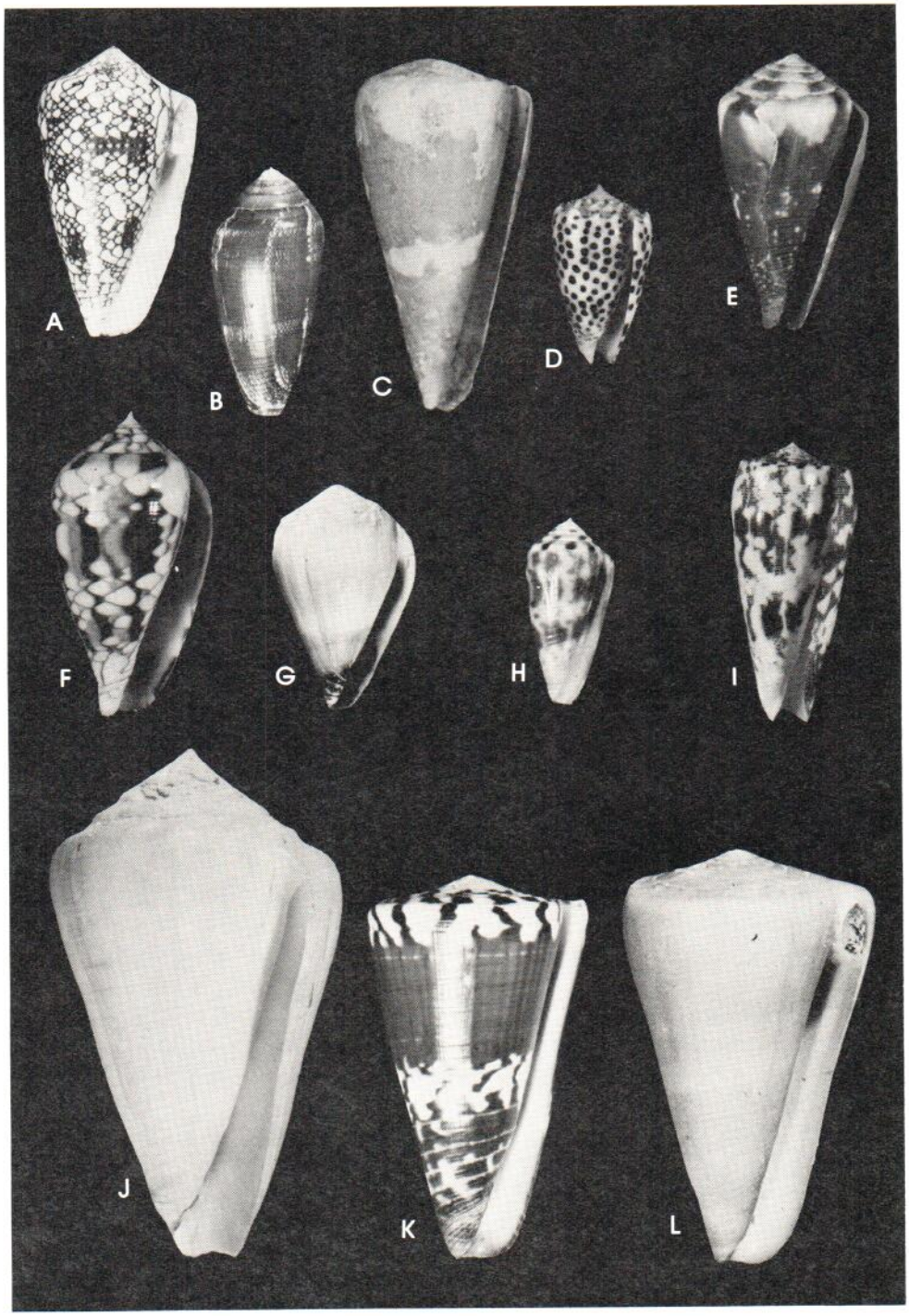


Figure 123.—**Conidae.** A. *Conus pennaceus*, length 60 mm. B. *C. pennaceus* color form, length 32 mm. C. *C. pertusus*, length 27 mm. D. *C. pulicarius*, length 65 mm. E. *C. rattus*, length 30 mm. F. *C. retifer*, length 40 mm. G. *C. sponsalis*, length 19 mm. H. *C. suturatus*, length 27 mm. I. *C. striatus*, length 90 mm. J. *C. quercinus*, length 130 mm. K. *C. vitulinus*, length 50 mm. L. *C. spiceri*, length 110 mm.

letely striate; last whorl obsoletely striate, the striae more pronounced basally. *Aperture:* rather broad, flaring slightly basally. *Color:* red- to yellow-brown with large white subtrigonal blotches grouped like scales; aperture white or blue-white. Periostracum thin, brown. *Animal:* foot pale brown mottled with darker brown; tip of siphon vermilion followed proximally by white and black bands (Kohn, 1959b).

C. pennaceus is one of the most common species of *Conus* on reef platforms, where it feeds on other mollusks such as *Haminoea crocata* and *Tricolia variablis* (Kohn, 1959a). In the laboratory these mollusks also feed on *Terebra gouldi* and *Cypraea maculifera* (Kohn, 1959a) and *Cypraea caputserpentis, C. moneta* and *Conus sponsalis* (Harrison, pers. comm.). Veligers settle immediately on hatching from the egg capsules (Kohn, 1961). Fossils are known from Pleistocene deposits on Molokai (Ostergaard, 1939 as *C. omaria).*

C. pennaceus is a well known species throughout the Indo-West Pacific.

Specimens of what have been considered a distinct species, *C. elisae* Kiener 1845, are often distinguished from typical *C. pennaceus* in collections. The shells are dark red-brown axially lineated with white (Fig. 122 B) and are merely variants of the typical pattern. Experimental evidence for this view has been provided by Perron (In press).

Conus pertusus Hwass in Bruguière, 1792. Fig. 123 C. Length, 27 mm; diameter, 13 mm. *Shell:* shoulder smooth, convex; pink with yellow or white. *Spire:* convex, rather obtuse. *Sculpture:* microscopically spirally striate, the striae grooved on the base. *Aperture:* rather narrow, sides parallel. *Color:* rose flaked with yellow or white, banded with two interrupted spiral bands of white or light pink blotches below the shoulder and centrally. Periostracum very thin, translucent, almost colorless, ornamented with widely spaced spiral ridges bearing small tufts. *Animal:* foot, siphon, rostrum, and tentacles pale golden yellow sparsely speckled with black (Kohn and Weaver, 1962).

These cones are uncommon, found at depths of 18 to 70 m. There.is a four-lobed veliger which metamorphoses when six whorls are complete, with a length of 2,100-2,200 μm (J. B. Taylor, 1975).

This species appears to be limited in its distribution to the Pacific Ocean.

Conus pulicarius Hwass in Bruguière, 1792. Fig. 123 D. Length, 87 mm; diameter, 37 mm. *Shell:* shoulder coronate, rounded; last whorl ventricose; white with six or eight spirals of dark brown or black spots. *Spire:* moderately elevated. *Sculpture:* spire striate and coronate; shoulder moderately coronate; last whorl smooth with spiral striae basally. *Aperture:* narrow, outer lip flaring slightly at the base. *Color:* white with six or eight spirals of dark brown to black spots, the spots often crowded into two bands, one on each side of the center of the last whorl; spire white marked sparingly with brown spots. Periostracum yellow and thin in juveniles, thick and brown in adults. *Animal:* foot and rostrum pale tan mottled with yellow or red-brown, siphon tipped with red-orange followed proximally by pale buff and black bands.

These cones are rather uncommon in shallow water where specimens occur in patches of sand on reef platforms and in areas shoreward of fringing reefs (Kohn, 1959a), but are abundant at depths of from 20 to 60 m. *C. pulicarius* feeds on

polychaete worms and an echiuroid (Kohn, 1959a). There is a four-lobed veliger larva and metamorphosis occurs when four or five whorls are complete, with a length of 1,220-1,250 μm (J. B. Taylor, 1975).

This species has been recorded throughout the Indo-West Pacific. It is reported as common in shallow water in Fiji (Cernohorsky, 1964b).

Conus quercinus Lightfoot, 1786. Fig. 123 J. (Synonym: *Conus cingulum* Martyn, Edmondson, 1933.) Length, 130 mm; diameter, 64 mm. *Shell:* shoulder smooth, rounded; last whorl solid, obese; with obsolete spiral striae becoming more pronounced basally; yellow. *Spire:* depressed, concave; apex raised. *Sculpture:* prominent spiral striae on the last whorl in juveniles, becoming obsolete in adults; spire striate. *Aperture:* wide, outer lip shouldered apically and flaring at the base. *Color:* yellow encircled with numerous closely spaced brown striae; spire usually paler yellow; aperture white. Periostracum thick, brown, opaque. *Animal:* foot and siphon brown-gray speckled with black (Kohn, 1959b).

C. quercinus is a sand-dweller, occurring in shallow sandy areas in bays and to depths of more than 80 m offshore. Large, adult specimens are commonly collected at depths of 2 to 6 m; juveniles are found at depths of 10 to 20 m.

This species occurs throughout the Indo-West Pacific.

Conus rattus Hwass in Bruguière, 1792. Fig. 123 E. (Synonym: *Conus taitensis* Hwass, Garrett, 1878.) Length, 37 mm; diameter, 21 mm. *Shell:* shoulder smooth, angular; last whorl moderately thick; yellow-brown or brown, spirally banded at the shoulder and centrally with white maculations; aperture violet. *Spire:* rather low, obtuse. *Sculpture:* last whorl with faint spiral striae which become more developed on the base. *Aperture:* rather narrow, sides nearly parallel. *Color:* yellow to violet-brown with large blue-white spots and maculations forming an interrupted central band and another at the shoulder; densely flecked with white below the central band; spire with brown and white blotches; aperture violet, outer lip light brown. Periostracum thin, yellow, translucent, smooth or with raised spiral ridges near the growing edge. *Animal:* foot, rostrum, and siphon dark olive green, mottled with black (Kohn, 1959b).

C. rattus is moderately common on benches and subtidal reef platforms. These cones feed exclusively on polychaetes (Kohn, 1959a). There is a four-lobed veliger larva and metamorphosis occurs when four whorls are complete (J. B. Taylor, 1975). Pleistocene fossils are known from Oahu (Ostergaard, 1928) and Maui (Ostergaard, 1939).

This species occurs throughout the Indo-West Pacific.

Conus retifer Menke, 1829. Fig. 123 F. Length, 40 mm; diameter, 22 mm. *Shell:* shoulder smooth and rounded; last whorl thick and solid; reticulated with orange-brown interrupted by large and small triangular white marks. *Spire:* elevated, acuminate. *Sculpture:* spire striate; last whorl axially striate becoming grooved at the base. *Aperture:* with almost parallel sides. *Color:* orange and brown with large and small triangular white markings arranged as scales, and axial bands of chocolate and orange which are usually interrupted forming two transverse bands; apex pink; aperture white

or pale pink. Periostracum thin, pale yellow, translucent. *Animal:* foot mottled brown; tip of siphon vermilion followed proximally by white and black bands.

These cones are rarely found, and appear to inhabit offshore areas at depths of more than 10 m.

C. retifer appears to be limited in its distribution to the Pacific Ocean.

Conus spiceri Bartsch and Rehder, 1943. Fig. 123 L. Length, 110 mm; diameter, 54 mm. *Shell:* shoulder smooth, angular; large and thick; pale yellow with obscure white bands. *Spire:* low, concave. *Sculpture:* fine spiral striae and closely spaced spiral threads becoming more distantly spaced basally; spire singly striate. *Aperture:* fairly broad, outer lip flaring basally. *Color:* pale yellow, darker basally, and with obscure white spiral bands; aperture blue-white. Periostracum thick, smooth, yellow-brown.

This is a rare species which occurs at depths of from 2 to 15 m, and is usually found buried in silt under coral heads (Cross, 1967b). *C. spiceri* preys on the polychaete *Loimia medusa* Savigny (Kohn, 1962).

C. spiceri was described from the Hawaiian Islands and also occurs in the Marshall Islands (Weaver, 1964b). Some malacologists consider *C. spiceri* a subspecies of *C. virgo* (Linnaeus, 1758) (see Trego, 1974).

Conus sponsalis Hwass in Bruguière, 1792. Fig. 123 G. (Synonyms: *Conus nanus* Broderip, Martens and Langkavel, 1871; *C. pusillus* Lamarck, Garrett, 1878; *C. ceylanensis* Hwass, Pease, 1868e.) Length, 19 mm; diameter, 11 mm. *Shell:* shoulder coronate; last whorl thick and solid; pale blue, shoulder white, base tipped with slate-purple. *Spire:* usually moderately elevated. *Sculpture:* variable — last whorl usually obsoletely striate, the striae more pronounced basally; shoulder may be coronated by somewhat obsolete small tubercles in small specimens. *Aperture:* narrow, sides parallel. *Color:* variable — last whorl usually pale blue with a spiral band of white at the shoulder; base tipped with slate or brown-purple and spire white; some specimens with spirals of red- or orange-brown and white dashes or dots on the last whorl; aperture violet, brown with white bands near the shoulder and centrally, outer lip edged with white. *Animal:* foot pale pink, mottled with white, darker pink at the extremities; siphon and rostrum pale pink or white tipped with darker; tentacles white (Kohn, 1959b).

C. sponsalis is one of the most abundant species of *Conus* on intertidal benches in Hawaii; although uncommon in deeper water, specimens have been dredged to depths of 100 m. These mollusks feed exclusively on polychaetes (Kohn, 1959a). There is a four-lobed veliger, and metamorphosis occurs when five whorls are complete (J. B. Taylor, 1975). Pleistocene fossils are known from Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939).

This species occurs throughout the Indo-West Pacific.

Conus striatus Linnaeus, 1758. Fig. 123 I. Length, 90 mm; diameter, 41 mm. *Shell:* shoulder smooth, angular; last whorl elongate-ovate, maximum diameter about one-fifth of the distance from shoulder to base; pink-white clouded with patches of closely spaced parallel brown lines. *Spire:* depressed below the shoulder, canaliculate. *Sculpture:* microscopic spiral striae becoming more noticeable at the base. *Aperture:*

broad, flaring gradually toward the base. *Color:* pink-white, irregularly clouded with blotches of brown or purple-brown consisting of closely spaced, parallel, spiral threads; spire tesselated with brown and white; aperture white. Periostracum thin, translucent, yellow. *Animal:* foot, siphon and rostrum tan mottled with brown.

Specimens of *C. striatus* are uncommon, typically found in moderately deep water, at depths of 8 to 15 m, in sand under large slabs of coral. *C. striatus* feeds on fishes (Kohn, 1959a). Pleistocene fossils are known from Oahu (Kohn, 1959b).

C. striatus occurs throughout the Indo-West Pacific. In Fiji it is reported as common in shallow water (Cernohorsky, 1964b).

Conus suturatus Reeve, 1844. Fig. 123 H. (Synonym: *Conus hawaiensis* Bartsch and Rehder, *nomen nudum,* Kaicher, 1956.) Length, 27 mm; diameter, 14 mm. *Shell:* shoulder smooth, angular; white with broad spiral bands of pale orange-brown. *Spire:* elevated in young individuals, less so in larger ones; canaliculate. *Sculpture:* spire deeply striate with a ridge on each whorl at the junction of the preceding whorl; last whorl spirally striated toward the shoulder. *Aperture:* narrow, sides parallel. *Color:* white, with broad spiral bands of pale orange-brown or orange-pink and spotted with the same color in the interspaces; spire maculated with brown; aperture white. In young specimens the spiral bands are orange-brown and often interrupted. Periostracum smooth, opaque, dark brown. *Animal:* siphon banded with white, black, and tan; rostrum and tentacles buff; upper portion of the foot white mottled with brown with a narrow, darker band posteriorly (Kohn and Weaver, 1962).

C. suturatus is common at depths of 40 to 150 m.

C. suturatus may be widely distributed in the Indo-West Pacific.

Conus textile Linnaeus, 1758. Fig. 124 C. (Synonym: *?Conus condensus* Sowerby, 1866.) Length, 80 mm; diameter, 38 mm. *Shell:* shoulder smooth, angular; maximum diameter of last whorl about one-fifth the distance from shoulder to base; white with bands of brown and yellow-brown reticulated by white triangles. *Spire:* elevated, concave, acuminate. *Sculpture:* spire striate; last whorl with axial growth striae. *Aperture:* broad, flaring basally. *Color:* white, with axial bands of brown and spiral bands of orange-brown interrupted by white triangles arranged as scales; spire similarly marked; aperture white. Periostracum thin, yellow, translucent. *Animal:* foot mottled brown on white; tip of siphon red-orange followed proximally by bands of white and black; remainder of siphon white with closely spaced narrow brown bands.

Specimens of *C. textile* are occasionally found in sand pockets on reef platforms but are more common at depths of 20 to 50 m where they occur under slabs of coral. These cones feed on other mollusks, such as *C. pennaceus, C. striatus, C. abbreviatus, C. ebraeus, C. lividus, Cypraea* spp., *Turbo argyrostomus, Thais aperta,* and *Drupa morum* (Kohn, 1959a).

This species occurs throughout the Indo-West Pacific; Cernohorsky (1964b) records it as common in shallow water in Fiji.

Conus vexillum Gmelin, 1791. Fig. 124 A, B. (Synonyms: *Conus sumatrensis* Hwass, Edmondson, 1933; *C. capitaneus* Linnaeus, Kohn, 1959b (smaller specimen).) Length, 85 mm; diameter, 57 mm. *Shell:* shoulder smooth, angular; white with broad spiral bands of yellow-brown stained with darker at the base and with axial streaks of

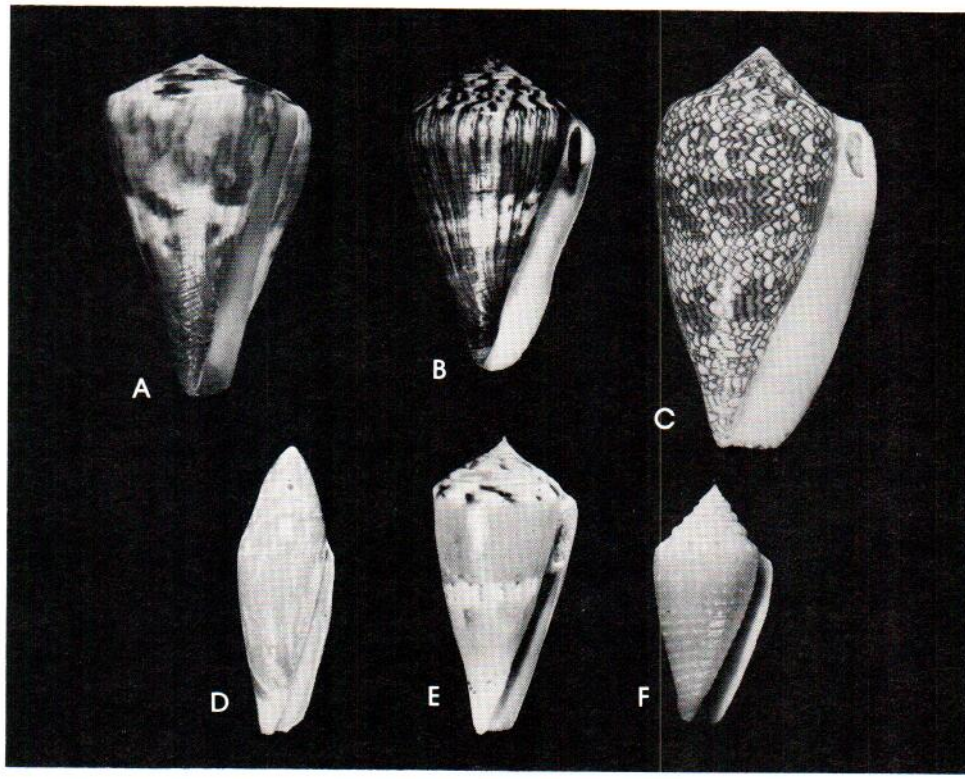


Figure 124.—**Conidae.** A, B. *Conus vexillum,* two color forms, length 75 mm (A), 122 mm (B). C. *C. textile,* length 97 mm. D. *C. cylindraceus,* length 38 mm. E. *C. sazanka,* length 40 mm. F. *C.* sp. cf. *granifer,* length 23 mm.

darker; aperture white. *Spire:* moderately elevated, obtuse. *Sculpture:* last whorl smooth, base faintly striate. *Aperture:* rather broad, sides parallel. *Color:* white, broadly banded with yellow-brown, with irregular, often branched, partially interrupted, chocolate axial lineations forming a white band at the middle and another at the shoulder; base stained with dark brown; interior of aperture white. In juvenile shells the ground color is dark yellow; with increasing size the color changes through olive to light yellow-brown, with the white spiral bands at the shoulder and centrally becoming more prominent (Kohn and Weaver, 1962). Periostracum dark green, thick, opaque, ridged. *Animal:* foot and siphon green-black.

C. vexillum is relatively uncommon, collected to depths of 50 m. This species feeds exclusively on polychaetes (Kohn, 1959a). There is a four-lobed veliger larva which metamorphoses when five and one half to six whorls are complete, at a columellar length of 2 mm (J. B. Taylor, 1975). Pleistocene fossils are known from Molokai (Ostergaard, 1939).

C. vexillum occurs throughout the Indo-West Pacific.

Conus vitulinus Hwass in Bruguière, 1792. Fig. 123 K. Length, 52 mm; diameter, 28 mm. *Shell:* shoulder smooth, angular; last whorl thick and solid; red-brown, darker at the base with a white band mottled with red-brown encircling the shoulder

and another at the center. *Spire:* depressed, slightly canaliculate. *Sculpture:* last whorl spirally striate, becoming ridged and granular at the base. *Aperture:* narrow, sides parallel. *Color:* usually deep red- or purple-brown at the shoulder and below the center; the white bands marked with one to several rows of brown dots; spire tesselated with brown and white. Periostracum gray, thick, opaque, closely spirally striate. *Animal:* visible portions of foot and siphon bright lemon yellow.

Shells are relatively uncommon on reefs, more frequently dredged at depths of 16 to 40 m. These cones feed on polychaetes (Kohn, 1959a). Larvae are *in capsulo* 14 to 15 days and hatch when their greatest dimension is 360 μm (Kohn, 1961); metamorphosis occurs when five whorls are complete and the columellar length is 1,600-1,700 μm (J. B. Taylor, 1975). Pleistocene fossils are known from Molokai (Ostergaard, 1939).

C. vitulinus occurs throughout the Indo-West Pacific; it is reported as a common species in shallow water in Fiji (Cernohorsky, 1964b).

Additional Records

Additional species of *Conus* reported from Hawaiian waters include: *Conus auricomus* Hwass in Bruguière, 1792 (Fig. 121 F), dredged at Midway, (Kohn, 1959b), fresh dead shell (Tiedeman, 1966); *C. aurisiacus* Linnaeus, 1758, dredged at depths of 110 to 210 m (Kohn and Weaver, 1962); *C. cylindraceus* Broderip and Sowerby, 1833, dredged at Midway (Kohn, 1959b); *C.* sp. cf. *granifer* Reeve, 1849, dredged at depths of 110 to 210 m (Kohn and Weaver, 1962); *C. luteus* Sowerby, 1833, dredged at depths of 110 to 210 m (Kohn and Weaver, 1962); *C. mitratus* Hwass in Bruguière, 1792, fossil (O'Brien, 1966); *C. sazanka* Shikama, 1970 (Fig. 124 E), dredged at depths of 70 to 200 m off Oahu (as *C.* sp. cf. *cumingii* Reeve, 1848, Kohn and Weaver, 1962); *C. sugillatus* Reeve, 1844, at 20 m in Maalaea Bay, Maui (Anon., 1970); and *C. tulipa* Linnaeus, 1758, fossil (Ostergaard, 1928), one live immature specimen at 16 m (Cross, 1965), one large fragment, Milolii, Kauai (Weaver, 1965a).

Family **Terebridae**

Terebrids are recognized by their elongate, slender, many-whorled shells with a short siphonal canal and small aperture. The shells in some species are almost completely smooth; in others they are prominently sculptured with axial ribs and/or spiral cords or threads. Most Hawaiian terebrids are found in relatively shallow water, with four species members of the infaunal community of surf-swept beaches, five or six found in sand pockets on fringing reefs, and as many as 20 species living in close proximity in subtidal sand flats at depths of 10 m.

Terebrids are sand-dwelling carnivores, specialized in their prey and in the morphology of the feeding aparatus. B. A. Miller (1970, 1975) who has studied many Hawaiian terebrids, suggests they feed on polychaete worms and hemichordates, and he identifies three proboscis types associated with their feeding habits. Terebrids with Miller's Type I proboscis have a short buccal tube and no radular apparatus and fall into two groups. In one group (*Terebra gouldi* is an example), the prey, shallow burrowing hemichordates such as *Ptychodera flava,* is grasped by the proboscis and engulfed whole (Fig. 128); in the other (*T. felina* is an example), the deep burrows of the polychaete *Dasybrachus* are probed by the foot before the worm is grasped by the

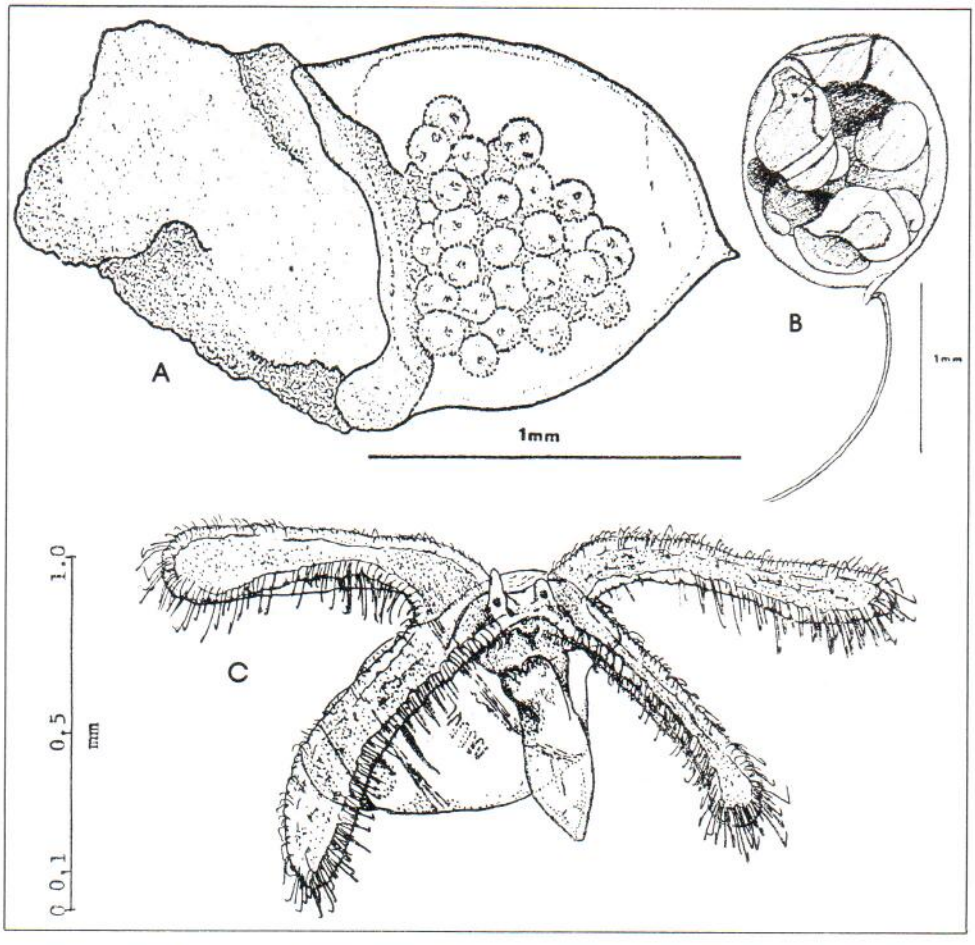


Figure 125.—**Terebridae.** A. Egg mass of *Hastula inconstans*. B. Egg capsules of *Terebra gouldi*. C. Pelagic veliger larva of *Hastula strigilata*. (A and B from B. A. Miller, 1970; C from J. B. Taylor, 1975.)

labial tube. Animals with Miller's Type II proboscis have a long buccal tube and a radular apparatus consisting of a venom gland and duct, and harpoonlike radular teeth. These terebrids (*Hastula inconstans* is an example) feed on spionid polychaetes *(Dispio magna)* which are slit open with the radular tooth, injected with venom and engulfed. Terebrids with Miller's Type III proboscis *(Terebra affinis* is an example) have a short buccal tube and no radular apparatus, but are distinguished by an accessory feeding organ in the labial tube. They may feed on the tentacles of cirratulid polychaetes.

The sexes are separate, and mating takes place on the surface of the sand *(Terebra gouldi* and *Hastula inconstans)* or several cm below the surface *(Terebra felina)* (Miller, 1970). The egg capsules are deposited on sand grains *(Terebra gouldi)* (Fig. 125 B), or basalt chips which make up part of the sand on some Hawaiian beaches *(Hastula inconstans)* (Fig. 125 A). Development is direct in *Terebra gouldi* (B. A. Miller, 1975) but most terebrids have a free-swimming veliger larval stage. Terebrid veliger larvae are remarkably similar, with four lobes; fat, short, stubby

cephalic tentacles; a foot with a well-developed, blunt, square propodium and tapering metapodium; and the velum is ingested at metamorphosis (Fig. 125) (J. B. Taylor, 1975).

Classification of the terebrids is unsatisfactory and the several genera and subgenera which have been proposed to accommodate shells with different textures and sculpture cut across the anatomical patterns proposed by B. A. Miller (1970). The three genera distinguished here are of necessity based on shell characters: *Hastula* with smooth, shiny shells and the sculpture of axial ribs and spiral punctae; *Terebra* with a distinct subsutural girdle defined by a groove or punctations, with smooth or axially ribbed and/or spirally threaded shells; and *Terenolla* with short, rather stubby shells, closely spaced axial ribs, and without a subsutural groove.

I have been conservative in distinguishing species, lumping some which others may consider distinct. Terebrid shells are, however, variable in sculpture, shape, and color. Size and sculptural differences have been demonstrated between male and female *Terebra crenulata* (B. A. Miller, 1966) and shells formerly attributed to two species, *T. cerithina* and *T. spaldingi*, appear to reflect differences in depth and perhaps habitat (Weaver, 1960). Thirty-one species of terebrids have been described from the Hawaiian Islands (one by Hinds, 1844; nine by Deshayes, 1859; nine by Pease, 1869b; nine by Pilsbry, 1921; one by Weaver, 1960; and two by Burch, 1965). Twenty of the names proposed are synonyms of species found elsewhere in the Pacific and Indo-West Pacific; six species may be endemic. I report 39 species, and an additional 9 which are very rare or with unconfirmed records.

Hastula albula Menke, 1843. Fig. 126 D. (Synonyms: *Terebra bipartita* Deshayes, 1859; *T. medipacifica* Pilsbry, 1921; *T. medipacifica melior* Pilsbry, 1921; *Hastula casta* Hinds 1844, Weaver, 1961.) Length, 22 mm; diameter, 6 mm. *Shell:* elongate-cylindrical; inflated; axially ribbed; white or pale brown, sometimes streaked or banded with dark brown. *Spire:* protoconch of five and one-half smooth, glossy pink whorls; teleoconch of five or six smooth, inflated whorls; suture oblique, constricted, crenulated by the axial ribs. *Sculpture:* axial ribs extending one-half the length to the entire length of the whorls; interspaces smooth, equal in diameter to the ribs. *Aperture:* elongate-ovate; base barely constricted; columella almost straight. *Color:* variable — white or pale brown, sometimes streaked or banded with orange-brown; apex often dark purple.

These gastropods are common in shallow water and to depths of 16 m where they live a few cm below the surface of the sand. The veligers hatch when one and one-half to two whorls are complete, add three and one-half whorls in the plankton and settle at lengths of 1.1 to 1.4 mm when five whorls are complete (J. B. Taylor, 1975).

H. albula was described from New Holland but is widely distributed in the Indo-West Pacific, from Mauritius to Micronesia and Polynesia. It is also reported from the Revillagigedo Islands off Mexico (Keen, 1971).

The shells of *H. albula* are distinguished from those of *H. inconstans* by the constricted base and larger protoconch.

Hastula contigua (Pease, 1871d). Fig. 126 I. (Synonyms: *Terebra assimilis* Pease, 1869b, non Angas, 1867; *T. clappi* Pilsbry, 1921.) Length, 17 mm; diameter, 4 mm. *Shell:* slender; axially ribbed with a spiral of punctures below the suture and fine

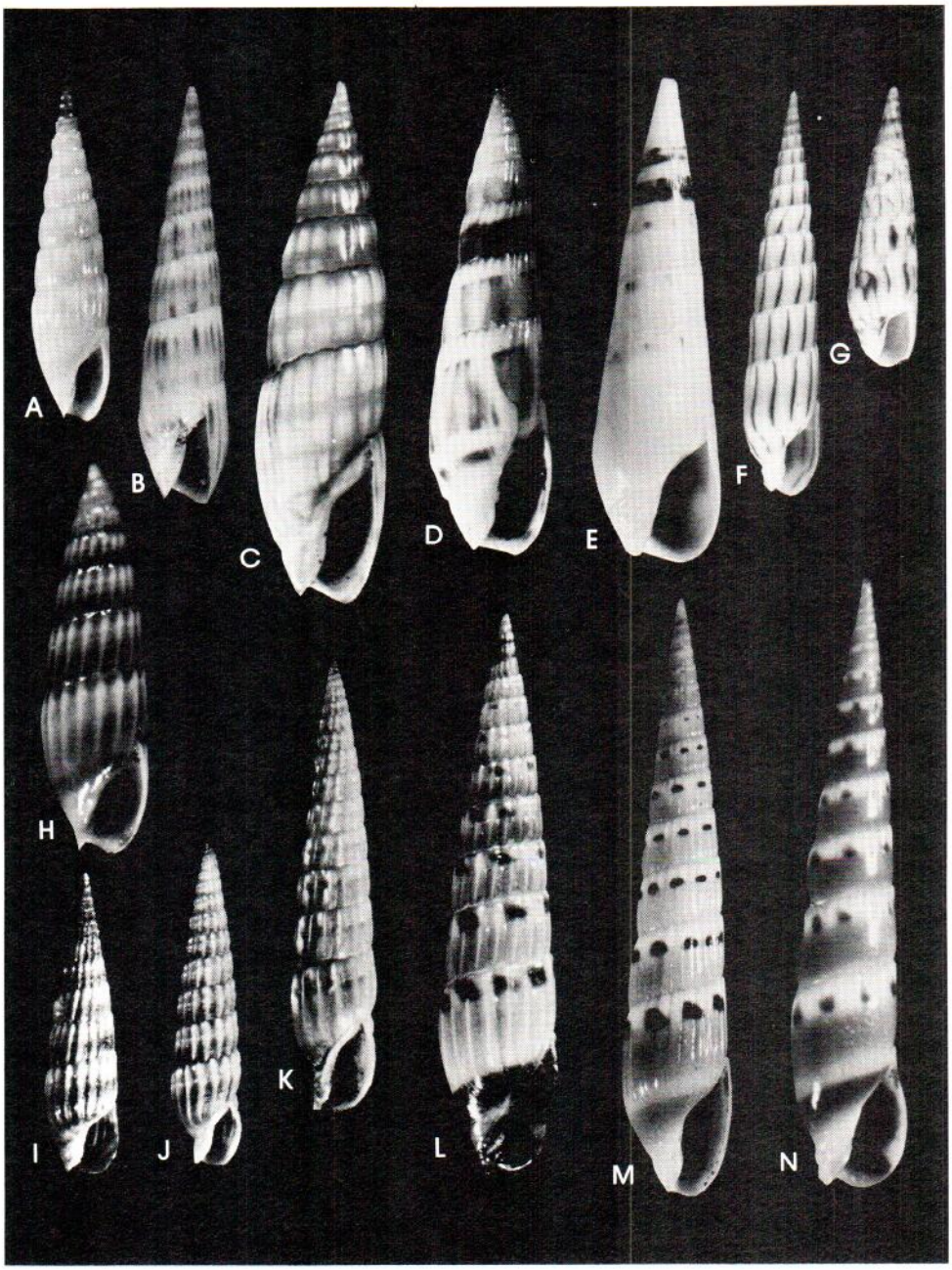


Figure 126.—**Terebridae.** A. *Hastula mera*, length 16 mm. B. *H. inconstans*, length 24 mm. C. *H. solida*, length 24 mm. D. *H. albula*, length 22 mm. E. *H. hectica*, length 52 mm. F. *H. lanceata*, length 38 mm. G. *H. penicillata*, length 26 mm. H. *H. tiedemani*, length 5 mm. I. *H. contigua*, length 16 mm. J. *H. swainsonii*, length 27 mm. K. *H. nitida*, length 25 mm. L. *H. matheroniana*, length 33 mm. M, N. *H. strigilata*, color forms (M) length 31 mm, (N) length 30 mm.

spiral striae; glossy, dark brown, ribs and a spiral band below the suture off-white. *Spire:* protoconch of three and one half conical whorls; teleoconch of eleven or more straight-sided whorls; suture slightly oblique, well impressed. *Sculpture:* straight, angulate axial ribs extending from suture to suture on each whorl and terminating abruptly on the base; a single spiral of punctures defining a subsutural band, the punctures sometimes slightly nicking the summits of the ribs; spiral striae between the ribs below the subsutural band. *Aperture:* ovate; columella straight or slightly twisted. *Color:* glossy, dark brown, ribs and subsutural band off-white.

These terebrids are found at depths of 30 to 150 m.

H. contigua was described from the Hawaiian Islands. Shells identified as representing this species were recorded from Canton Island (Burch, 1962).

Hastula hectica (Linnaeus, 1758). Figs. 6 B; 126 E. (Synonym: *Terebra corpulescens* Lamarck, Martens and Longkavel, 1871.) Length, 52 mm; diameter, 11 mm. *Shell:* awl-shaped, anteriorly ventricose; smooth; white to dark chocolate. *Spire:* ten or more whorls exclusive of the protoconch; apex usually lacking; suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* ovate, flaring. *Color:* variable — white with occasional chocolate blotches to dark brown.

These terebrids are uncommon, found in fine sand on surf-swept beaches, sometimes above the line of high tide. They feed on a spionid polychaete, *Nerinides* sp. (B. A. Miller, 1970).

H. hectica occurs throughout the Indo-West Pacific.

Hastula inconstans (Hinds, 1844). Fig. 126 B. (Synonyms: *Terebra aciculina* Reeve, 1860, in part; *T. inconstans confusa* Smith, 1877, Pilsbry, 1921; *Hastula confusa* Smith, 1877, Weaver, 1960.) Length, 24 mm; diameter, 6 mm. *Shell:* slender, attenuate; base of outer lip truncate; axial ribs extending the length of the whorls; glossy, white with axial brown streaks or all brown. *Spire:* protoconch attenuate, inflated, conical to peglike, of three and one-half whorls; suture oblique, constricted, crenulated by the axial ribs. *Sculpture:* keeled axial ribs approximately equal in diameter to the smooth interspaces and extending the length of the whorls. *Aperture:* ovate, flared, the outer lip abruptly truncate at the base. *Color:* variable — white or cream axially streaked with threads or bands of dark brown, sometimes brown with a white band below the suture.

H. inconstans occurs on surf-washed beaches with fine, well-sorted sand, gentle slope, and rolling breakers 1 to 2 m in height. B. A. Miller (1970) has described the feeding habits and egg capsules. When feeding, these terebrids "sail" in the surf by means of the large foot. They feed exclusively on the spionid polychaete *Dispio magna,* injecting a toxin into the prey by means of the radular apparatus. Egg capsules are deposited on basalt fragments in the surge area just beyond the zone where the surf breaks. The veligers hatch when one whorl is complete, add two and one-half whorls while planktonic, and settle at columellar lengths of 650 to 850 μm when three to three and one-half whorls are complete (J. B. Taylor, 1975).

H. inconstans was described from the Hawaiian Islands and may be endemic. Sowerby (1844), who obtained his information from Hinds, noted that "it abounds in the sands in considerable numbers." The truncate base of the outer lip is characteristic.

Hastula lanceata (Linnaeus, 1767). Fig. 126 F. (Synonym: *Terebra lanceata oahuensis* Pilsbry, 1921.) Length, 38 mm; diameter, 6 mm. *Shell:* subulate, shining; smooth; white lineated with brown. *Spire:* tapering, acute; protoconch of five and one-half conical tan whorls; teleoconch of 15 to 18 flat whorls; suture impressed. *Sculpture:* apical whorls axially plicate, abapical whorls smooth and polished, occasionally with faint axial ribs. *Aperture:* ovate; base constricted; columella with a prominent raised cord on the outer margin. *Color:* white with wavy red-brown axial lineations interrupted on the last whorl by a white spiral below the periphery.

Specimens of *T. lanceata* are uncommon, found at depths of 3 to 100 m. The veligers are among the largest of terebrid veligers and may be between 1.2 and 1.6 mm in columellar length; they settle when four and one-quarter to five and one-half whorls are complete (J. B. Taylor, 1975).

Pilsbry (1921) distinguished the Hawaiian shells as a subspecies because of the axial ribs on the last whorl; these ribs appear in specimens from other areas in the Indo-West Pacific, however, and recognition of a Hawaiian subspecies seems unnecessary. The shells are distinguished from those of *H. penicillata* by the wide-spaced axial marks, narrower aperture, and size of the protoconch.

Hastula matheroniana (Deshayes, 1859). Fig. 126 L. (Synonym: *Terebra lauta* Pease, 1869b.) Length, 33 mm; diameter, 5 mm. *Shell:* subcylindrical; shining; axially ribbed, with a single spiral row of punctures below the suture; light to dark brown or gray with a single row of chestnut spots below the suture. *Spire:* protoconch of two or three light brown, smooth whorls; teleoconch of ten or more whorls; suture impressed, oblique. *Sculpture:* keeled, sharp axial ribs, 17 on the last whorl 5 mm in diameter, extending from suture to suture and equal in diameter to the interspaces but disappearing at the periphery of the last whorl; with a single row of punctures between the ribs below the suture. *Aperture:* ovate; columella twisted; base constricted. *Color:* variable — dark to light brown with a pale band bearing a row of chestnut spots below the suture; base dark brown.

Specimens are not uncommon, found at depths of from 5 to 100 m off Oahu and Maui.

H. matheroniana was described from Tahiti and also occurs in the Philippine Islands (as *H. lauta,* Burch, 1962), Western Australia, New Guinea, and Fiji (as *H. lauta,* Cernohorsky and Jennings, 1966). Tomlin (1944) and Bratcher (1977) consider *H. lauta* Pease described from the Hawaiian Islands a synonym.

Hastula mera (Hinds, 1844). Fig. 126 A. (Synonym: *Terebra bacillus* Deshayes, 1859.) Length, 17 mm; diameter, 3.5 mm. *Shell:* slender; almost smooth, suture crimped; glossy, fawn spirally banded with white and with a spiral of brown spots. *Spire:* protoconch of about one and one-half inflated whorls; teleoconch of 10 straight-sided whorls; suture oblique, impressed, microscopically crimped. *Sculpture:* smooth except for occasional obsolete axial folds extending from the crimped suture. *Aperture:* narrowly ovate; columella nearly straight. *Color:* glossy, pale fawn, spirally banded with white below the suture and with a spiral of angular chestnut brown spots at the base of the white spiral.

These delicate, little terebrids are uncommon, found at depths of less than a meter in fine sand and dredged at depths to 60 m.

H. mera was described from the Strait of Malacca, and *T. bacillus* from the Hawaiian Islands.

Hastula nitida (Hinds, 1844). Fig. 126 K. (Synonym: *Hastula lepida* Weaver 1961, non Hinds, 1843.) Length, 25 mm; diameter, 5 mm. *Shell:* slender; axially ribbed, with a single spiral of punctures below the suture; glossy, pale gray or fawn. *Spire:* protoconch of four conical dark brown or purple whorls, the abapical whorls convex and oblique; teleoconch of 13 or more straight-sided whorls; suture oblique, impressed, barely crenulating the axial ribs. *Sculpture:* sharply angled axial ribs extending from suture to suture on each whorl but sometimes becoming obsolete on the last whorl, interspaces equal in diameter to the ribs, smooth and shallow; a single row of punctures between the ribs and about halfway down each whorl. *Aperture:* ovate; columella barely twisted. *Color:* pale gray or fawn, sometimes with a white spiral at the suture; protoconch dark brown or purple.

These terebrids are fairly common at depths of from 10 to 160 m. The veligers hatch when one whorl is complete, add three more while in the plankton, and settle when 1.0 to 1.1 mm in length and when four to four and one-quarter whorls are complete (J. B. Taylor, 1975).

H. nitida was described from the Marquesas Islands and is known from other localities in the Pacific.

The distinguishing feature of *H. nitida,* as Hinds pointed out, is that "the girdling line which traverses the upper part of each whorl does not cross the ribs." Although Weaver (1961) states that the inner lip has a raised edge, this feature appears to be variable.

Hastula penicillata Hinds, 1844. Fig. 126 G. (Synonym: *Terebra betsyae* Burch, 1965.) Length, 26 mm; diameter, 5 mm. *Shell:* elongate, glossy; axially ribbed almost the entire length of the whorls and with the subsutural band defined by a spiral of punctures; white axially lineated with brown. *Spire:* protoconch conic, inflated, of about four whorls, teleoconch elongate, tapering; suture impressed. *Sculpture:* angulate axial ribs extending almost the entire length of the whorls; sutural groove usually defined by a spiral of minute punctures. *Aperture:* ovate; canal straight. *Color:* creamy white lineated by bifurcating or netlike brown lines extending from suture to suture.

These terebrids are fairly common at depths of from 2 to 18 m. They feed on a spionid polychaete (B. A. Miller, 1970). The veligers hatch when one and one-quarter whorls are complete, add three more whorls in the plankton, and settle at lengths of 900 to 1000 μm when four to four and one-half whorls are complete (J. B. Taylor, 1975).

H. penicillata is a well-known species throughout the Indo-West Pacific.

Burch (1965) distinguished *Terebra betsyae* by its punctured sutural groove; Cernohorsky and Jennings (1966) suggest that the occurrence of pits is a variable feature in this species.

Hastula solida Deshayes, 1857. Fig. 126 C. Length, 26 mm; diameter, 6 mm. *Shell:* subulate, inflated; glossy; axially striate; cream with flesh striations and spiral bands. *Spire:* straight, of nine inflated but not convex whorls plus the protoconch;

suture oblique, irregular because of axial striae. *Sculpture:* flat axial ribs with impressed grooves between. *Aperture:* ovate; outer lip flaring basally; siphonal canal straight. *Color:* cream, axial grooves flesh, with three gray spiral bands on the last whorl and a single band on the others.

These terebrids are rarely found, usually at depths of 120 m.

H. solida was described from Japan and is found through the tropical Pacific.

Hastula strigilata (Linnaeus, 1758). Figs. 126 M, N. (Synonyms: *Hastula verreauxi* Deshayes, Tinker, 1958; *H. diversa* Weaver, 1960 non E. A. Smith, 1901.) Length, 31 mm; diameter, 6 mm. *Shell:* slender, polished; with close-set axial ribs and deep interspaces; dark gray encircled below the suture by a white band studded with angular brown blotches. *Spire:* protoconch of about three glossy brown whorls; teleoconch of 10 to 15 flat-sided whorls; suture barely impressed. *Sculpture:* close-set, broad, flat, obliquely oriented axial ribs separated by narrow grooves. *Aperture:* narrow; columella slightly concave. *Color:* dark gray, each whorl encircled below the suture by a white band set with angular dark brown blotches, last whorl with a narrow white band below the periphery, base white.

This is a fairly common species on surf-swept beaches and at depths to 100 m. It feeds on a spionid polychaete, *Nerinides* sp. (B. A. Miller, 1970). The veligers hatch when one whorl is complete, add two or more whorls while planktonic and settle at a columellar length of 875 to 895 μm when three and one-quarter to three and one-half whorls are complete (J. B. Taylor, 1975). Shells are variable in sculpture and color pattern.

H. strigilata occurs in the Pacific, in the Philippines, and in Fiji (Cernohorsky and Jennings, 1966).

Hastula swainsonii (Deshayes, 1857). Fig. 126 J. (Synonyms: *Terebra sulcata* Pease, 1869b; *T. swainsonii* var. *inflexa* Pease, 1869b.) Length, 27 mm; diameter, 6 mm. *Shell:* tapering; axially ribbed; subsutural band defined by a series of punctures between the ribs; interspaces between the ribs with microscopic spiral striae; dark gray. *Spire:* protoconch of four and one-half or five conical, red-brown whorls; teleoconch of 15 convex whorls; suture deep, crenulated by the axial ribs. *Sculpture:* subsutural groove defined by a series of punctures between the ribs; coarse, elevated axial ribs extending from suture to suture but sometimes not continuous over the last whorl; interspaces of about the same diameter as the ribs and microscopically spirally striated or with deep grooves. *Aperture:* ovate; base and outer lip constricted; outer lip indented by spiral punctures of the subsutural band. *Color:* dark gray.

These terebrids are common at depths of 10 to 100 m. The veligers hatch when one and one-half whorls are complete, add three to three and one-half whorls in the plankton, and metamorphose at lengths of 925 to 1025 μm when four and one-half to five whorls are complete (J. B. Taylor, 1975).

This species is known from the tropical Pacific.

The shells are distinguished from those of *H. nitida* by the spiral striae in the interspaces between the ribs.

Hastula tiedemani Burch, 1965. Fig. 126 H. Length, 4.5 mm; diameter, 1.10 mm. *Shell:* subulate, shining; with oblique, straight axial ribs; cinnamon brown,

splashed with white on the back. *Spire:* protoconch of four and one-half inflated, slightly excentric whorls; teleoconch of four rather straight-sided whorls; suture impressed. *Sculpture:* bold, oblique axial ribs, about 11 on the last whorl 1 mm in diameter, separated by smooth interspaces of about the same diameter as the ribs; ribs extending from suture to suture and below the periphery of the last whorl. *Color:* dark cinnamon brown, ribs light gray and usually with a band of white on the back of the outer lip; aperture white.

These terebrids are found, often in dense colonies, at depths of about 10 m on the leeward coast of Oahu.

H. tiedemani was described from the Hawaiian Islands.

Terebra achates Weaver, 1960. Fig. 127 D. Length, 56 mm; diameter, 10 mm. *Shell:* elongate, slender; subsutural band defined by a deep spiral groove; remaining part of whorls with fine axial and spiral striae; white with two spiral rows of brown spots. *Spire:* protoconch of three conical whorls; whorls of teleoconch convex, indented at the channelled suture. *Sculpture:* subsutural band of two spirals, the apical larger and with axial nodules, the abapical smaller; remainder of whorls with fine axial and punctate spiral striae. *Aperture:* ovate; columella twisted. *Color:* white with two spiral rows of brown spots, three on the last whorl.

These terebrids are found at depths of from 3 to 100 m, usually in fine sand.

T. achates was described from the Hawaiian Islands. The shells are distinguished from those of *T. consobrina* Deshayes, 1857 from the Indian Ocean by their proportionately smaller whorls and fewer spots, and from those of *T. subulata* which also occurs in Hawaii by the punctate spiral striae.

Terebra affinis Gray, 1834b. Fig. 130 E. (Synonyms: *Terebra peasei* Deshayes, 1859; *T. flavescens* Weaver, 1960, non Deshayes, 1859; *T. puncticulata* Deshayes, Reeve, 1860.) Length, 42 mm; diameter, 8 mm. *Shell:* subulate, inflated; subsutural band distinct; axially ribbed by flat cords, interspaces punctate; cream with light yellow or orange. *Spire:* protoconch of four and one-quarter to four and three-quarters whorls; whorls of teleoconch convex; suture constricted. *Sculpture:* low, flat axial ribs, the interspaces narrow and spirally punctate; subsutural band flat, defined by a groove which crosses the ribs and interspaces. *Aperture:* ovate; base constricted; columella straight with a low fold. *Color:* cream or yellow, faintly blotched with brown or orange.

This terebrid is common in shallow, protected areas of sand and coral rubble at depths of from 1 to 200 m. It has an accessory feeding organ in the labial cavity and probably feeds on the bright red cirratulid polychaete *Cirriformia* sp. which lives buried beneath the surface of the sand or in small holes in coral (B. A. Miller, 1970). The veligers hatch when one and one-quarter whorls are complete, add three more whorls while they are planktonic, and settle at lengths of 1.0 to 1.1 mm when four and one-quarter to four and three-quarters whorls are complete (J. B. Taylor, 1975).

T. affinis is found from the east coast of Africa through the Indo-West Pacific to Micronesia (Marshall Islands) and Polynesia, and in the Gulf of California (Keen, 1971).

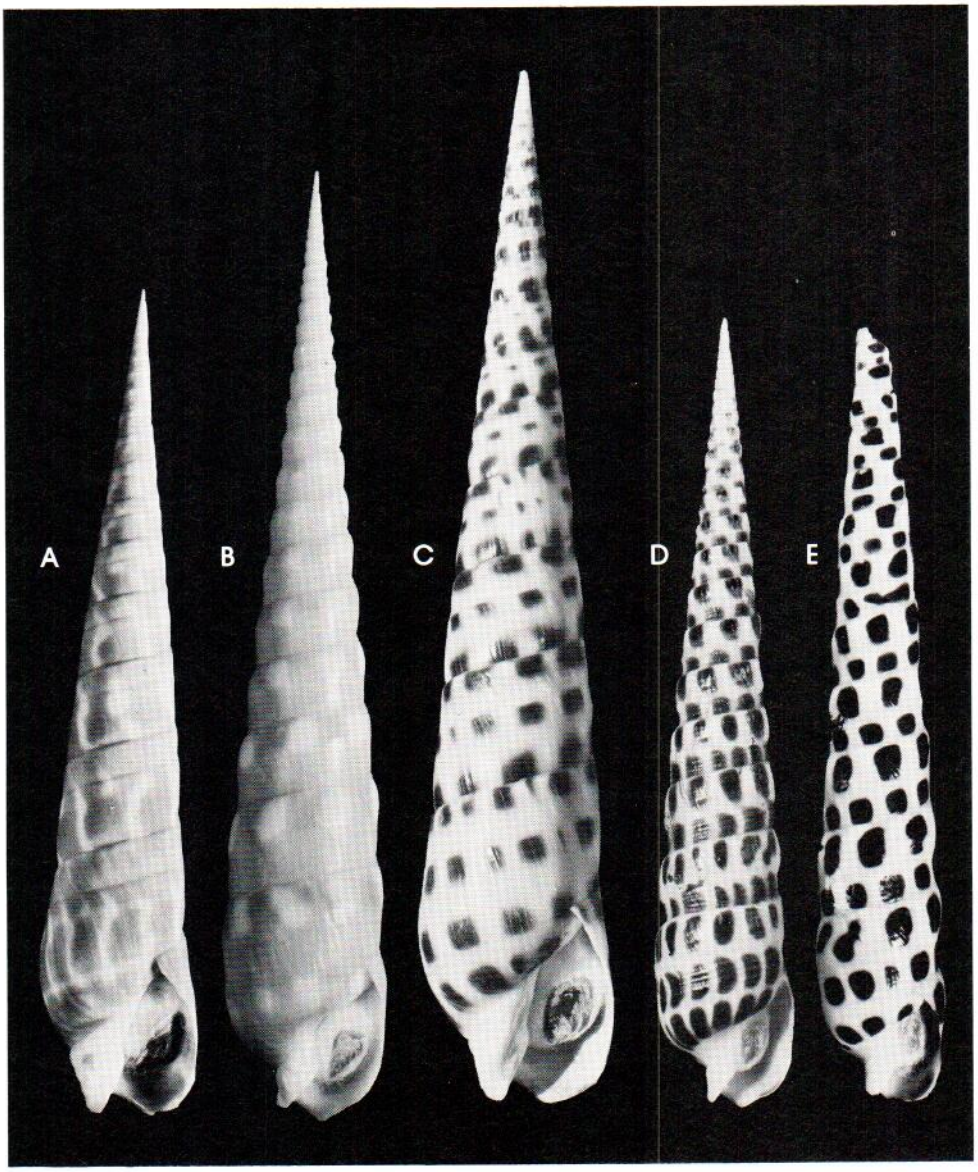


Figure 127.—**Terebridae.** A. *Terebra dimidiata,* length 115 mm. B. *T. guttata,* length 110 mm. C. *T. areolata,* length 120 mm. D. *T. achates,* length 56 mm. E. *T. subulata,* length 60 mm.

Terebra amanda Hinds, 1844. Fig. 130 I. (Synonym: *Terebra straminea* Gray, Weaver, 1960.) Length 40 mm; diameter, 8 mm. *Shell:* subulate, slender; with a double row of sutural nodules and punctate spiral grooves; cream to light brown. *Spire:* protoconch of about three conical whorls; teleoconch of 14 to 18 slightly inflated whorls; suture oblique, indented. *Sculpture:* sutural band defined by a deep spiral groove, often punctate, which separates two rows of distinct, slightly concave rows of beads, the apical row more prominently developed than the abapical row;

spiral sculpture of three or four rows of deep punctures. *Aperture:* ovate; columella slightly twisted. *Color:* cream to light brown.

These terebrids have been found at depths of 10 to 20 m.

T. amanda is found throughout the Indo-West Pacific.

Terebra areolata (Link, 1807). Fig. 127 C. (Synonyms: *Terebra muscaria* Lamarck, Tinker, 1952; *T. aureolata* [sic] Link, Tinker, 1958.) Length, 140 mm; diameter, 22 mm. *Shell:* slender, shining; surface of last whorl smooth; whorls with a depressed sutural band; cream with three rows of brown spots on each whorl. *Spire:* protoconch of about three and one-half peglike whorls; cream to yellow tan; straight; whorls flush; suture impressed. *Sculpture:* apical whorls axially plicate, later whorls smooth except for the sutural band which occupies about one-third of each whorl as a slightly depressed portion of the whorl. *Aperture:* ovate; columella twisted. *Color:* white or cream with three rows of somewhat angular brown spots on each whorl.

T. areolata occurs at depths of 3 to 5 m in areas of fine sand. It feeds on the enteropneust *Ptychodera flava* at Enewetak, Marshall Islands (B. A. Miller, 1966). The veligers hatch when one whorl is complete, add two to two and one-half whorls, and settle at lengths of 725-825 μm when three and one-half whorls are complete (J. B. Taylor, 1975).

This species occurs throughout the Indo-West Pacific, from East Africa through the tropical Pacific.

Terebra argus brachygyra Pilsbry, 1921. Fig. 129 A. (Synonym: *Terebra flavescens* Deshayes, 1859.) Length, 40 mm; diameter, 8 mm. *Shell:* somewhat ventricose, solid; subsutural band defined by a punctate spiral groove; with obsolete, oblique axial ribs; white with pale buff spots. *Spire:* thin and tapering, the apical portion often slightly flexed; teleoconch of ten or more whorls; suture impressed. *Sculpture:* obsolete axial ribs crossed by a punctate spiral groove defining the axially ribbed subsutural band which occupies about one-half of each whorl; remaining sculpture of obsolete axial ribs. *Aperture:* ovate; columella twisted; base constricted. *Color:* variable — white, occasionally with three series of buff spots.

These terebrids are uncommon, found in both shallow and deep water.

The Hawaiian shells were distinguished from the wide-ranging Indo-West Pacific form by Pilsbry (1921), because of their consistently smaller size, less oblique whorls, and distinct axial ribs.

Terebra babylonia Lamarck, 1822. Fig. 130 H. Length, 45 mm; diameter, 7 mm. *Shell:* elongate, tapering, the whorls barely convex; subsutural band of oblong beads defined by a deep spiral groove; spiral sculpture predominant, with axial striae; flesh with orange-brown axial threads. *Spire:* protoconch of three and one-half conical whorls; whorls slightly convex; suture indented. *Sculpture:* subsutural band defined by a deep spiral groove, of two rows of oblong beads on the axial whorls and one on the later whorls; remainder of whorls with spiral grooves and axial striae. *Aperture:* ovate; columella twisted. *Color:* sutural band white, remainder of whorls flesh streaked with orange-brown.

These terebrids are found at depths of from 1 to 200 m.

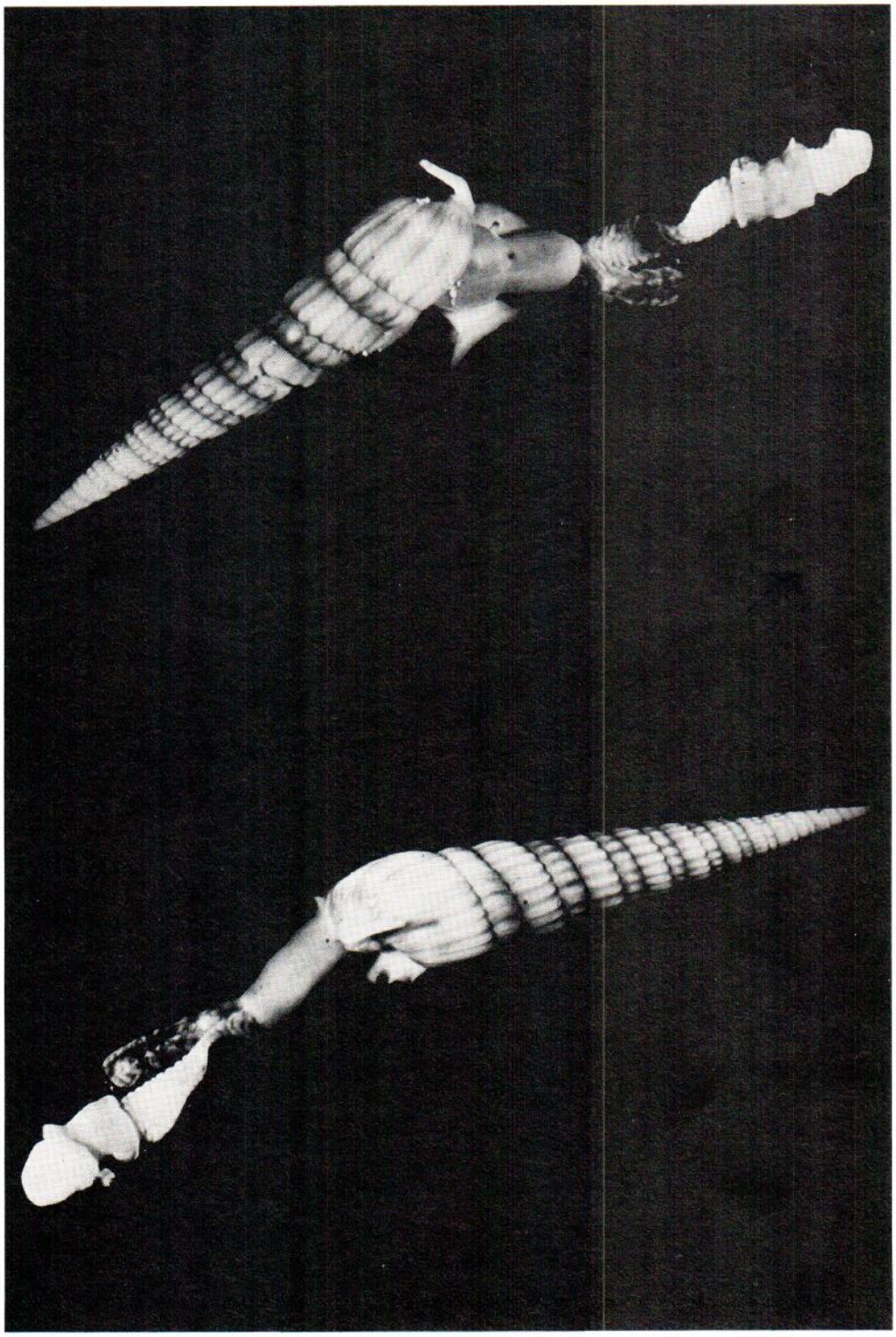


Figure 128.—*Terebra gouldi* feeding on the hemichordate, *Ptychodera flava*. (Photos by B. A. Miller, 1970.)

T. babylonia occurs throughout the Indo-West Pacific from the Persian Gulf to Polynesia and Micronesia.

Terebra cerithina Lamarck, 1822. Fig. 129 B. (Synonym: *Terebra spaldingi* Pilsbry, 1921.) Length, 31 mm; diameter, 8 mm. *Shell:* narrow to ventricose, polished; subsutural groove punctate; axial ribs flattened; white or cream with flesh-color. *Spire:* apex tapering but not attenuate; 12 or more moderately inflated whorls; suture oblique and impressed. *Sculpture:* smooth, rounded axial ribs interrupted by a well-impressed punctate sutural groove; interspaces between the ribs of lesser diameter, smooth. *Aperture:* ovate; base constricted. *Color:* white, the intercostal spaces flesh-colored.

These terebrids are uncommon, in both shallow and deep water.

T. cerithina occurs in the western Pacific Ocean (Cernohorsky and Jennings, 1966).

Weaver (1960) distinguishes two forms in Hawaiian waters, a small, narrow, deep-water form distinguished by Pilsbry (1921) as *T. spaldingi,* and a large, ventricose shallow-water form. Consistent differences between the Hawaiian shells and those from elsewhere in the Pacific are not identifiable and there seems little basis for the recognition of a Hawaiian subspecies.

Terebra chlorata Lamarck, 1822. Fig. 129 I. Length, 44 mm; diameter, 12 mm. *Shell:* conical, solid; smooth with a subsutural groove; white with spirals of brown flamelike markings. *Spire:* protoconch of three or four smooth, yellow whorls; teleoconch of ten or more straight-sided whorls; suture barely indented. *Sculpture:* apical whorls axially ribbed; sutural groove and microscopic growth striae on abapical whorls. *Aperture:* ovate, flaring; columella straight or twisted. *Color:* white; sutural band blotched with brown, remainder of whorl axially lineated with brown and with a row of brown spots at the base.

These terebrids are found in shallow water and to depths of 18 m in reef pockets. They feed exclusively on the capitellid *Dasybranchus caducus* (Grube, 1846) (B. A. Miller, 1970).

T. chlorata occurs throughout the Indo-West Pacific.

Terebra columellaris Hinds, 1844. Fig. 130 B. (Synonyms: *Terebra propinqua* Pease, 1869b; *T. flavofasciata* Weaver, 1960 non *flavofasciata* Pilsbry, 1921.) Length, 40 mm; diameter, 7 mm. *Shell:* slender, narrow; subsutural band defined by a shallow groove, of flat beads; remainder of whorls with flat, sinuous axial ribs, interspaces with spiral threads; russet spirally banded with white. *Spire:* protoconch of four narrow, conical whorls; teleoconch of 15 or more whorls; whorls straight-sided with a constricted suture. *Sculpture:* wavy, narrow, flat, rounded axial ribs, 29 on the last whorl 8 mm in diameter, ribs and interspaces equal in diameter, interspaces shallow and spirally grooved; subsutural band set off by shallow pits in the interspaces and on the ribs. *Aperture:* ovate; columella and siphonal canal twisted. *Color:* cream to russet splashed with white, the interspaces between the ribs usually darker red.

These terebrids are uncommon, found at depths of from 50 to 200 m.

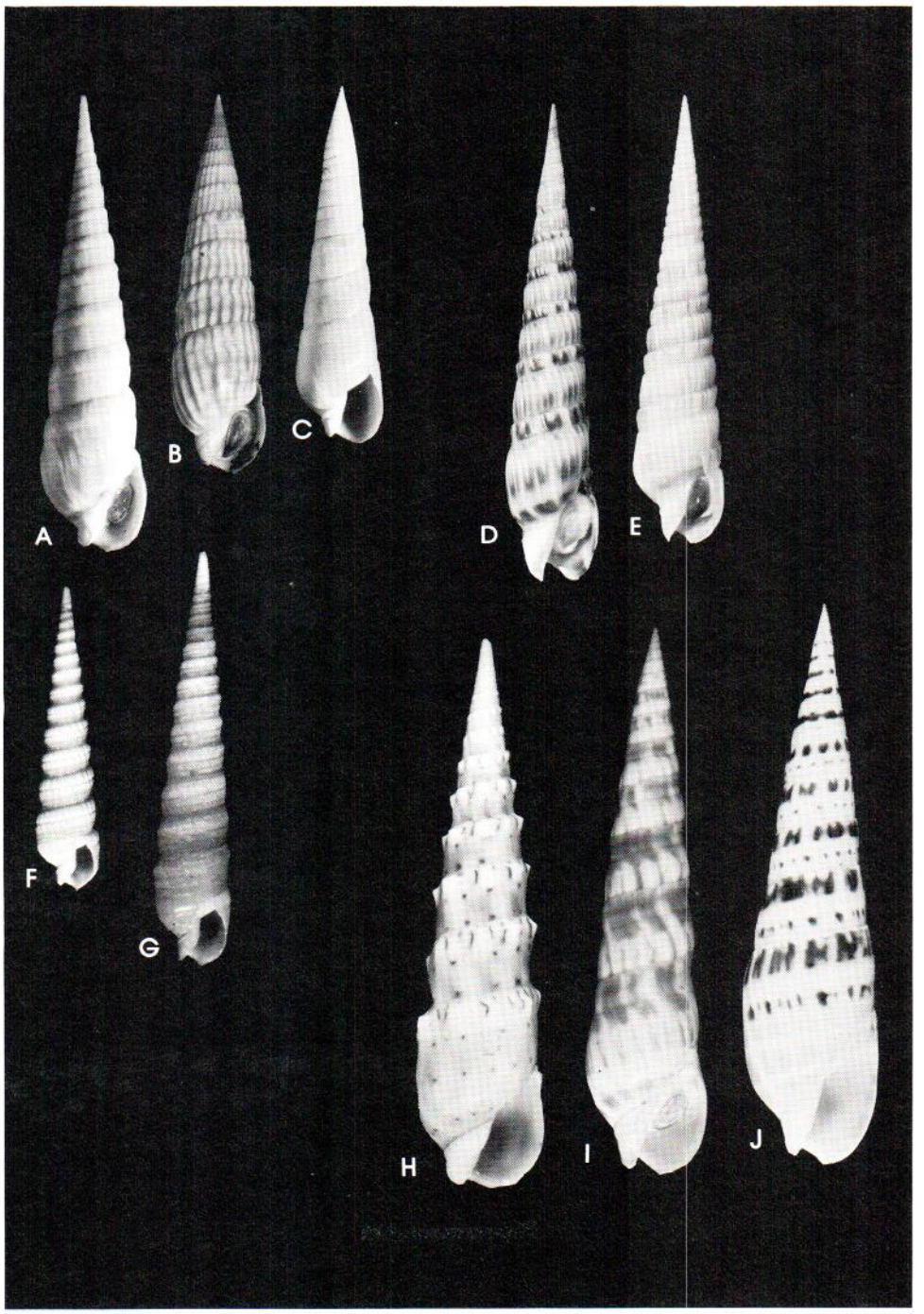


Figure 129.—**Terebridae.** A. *Terebra argus brachygyra,* length 40 mm. B. *T. cerithina,* length 30 mm. C. *T. felina,* length 35 mm. D. *T. gouldi,* length 50 mm. E. *T. thaanumi,* length 50 mm. F. *T. nodularis,* length 37 mm. G. *T. funiculata,* length 40 mm. H. *T. crenulata,* length 100 mm. I. *T. chlorata,* length 40 mm. J. *T. maculata,* length 100 mm.

T. columellaris is found in the Philippines and throughout the tropical central Pacific (Cernohorsky and Jennings, 1966). The shells are distinguished from those of *T. undulata* by their more slender outline, shorter whorls, narrower subsutural band, and russet color.

Terebra crenulata (Linnaeus, 1758). Fig. 129 H. (Synonyms: *Terebra crenulata fimbriata* Deshayes, Pilsbry, 1921; *T. interlineata* Deshayes, 1859.) Length, 121 mm; diameter, 26 mm. *Shell:* attenuate, solid; sutural band sharply noduled, cream spotted and lineated with chestnut. *Spire:* protoconch of about four and one-quarter whorls; teleoconch of ten to twelve whorls; suture shallow and sinuous. *Sculpture:* apical whorls axially ribbed, remaining whorls smooth except for growth striae; sutural band usually consisting of sharp nodules but sometimes smooth. *Aperture:* ovate; columella with a faint fold. *Color:* cream to fawn, the periphery of each whorl spirally maculated with brown, a spiral of chestnut spots below the sutural band, and with chestnut lineations between the nodules of the sutural band.

This terebrid is common in sandy areas from depths slightly below mean low water to depths of more than 100 m. In shallow water these mollusks occur where there is little or no wave action and soft sand in the same habitat as *T. gouldi*, and in coarse sand pockets on subtidal reefs. They feed on a large hemichordate (B. A. Miller, 1970).

T. crenulata occurs throughout the Indo-West Pacific, and in the Revillagigedo Islands off Mexico (Keen, 1971). Deshayes' *T. interlineata* was described from the Hawaiian Islands but the shells are merely variants of the widespread species.

Terebra dimidiata (Linnaeus, 1758). Fig. 127 A. Length, 115 mm; diameter, 24 mm. *Shell:* attenuate, solid; smooth except for a prominent spiral subsutural groove; reddish-white with axial white marks. *Spire:* attenuate, of 20 or more whorls exclusive of the protoconch; whorls rather straight-sided; suture indented. *Sculpture:* apical whorls axially ribbed; abapical whorls smooth; sutural band delimited by a spiral groove. *Aperture:* wide; canal with a strong groove; columella straight. *Color:* red-orange banded with axial flashes of white, last whorl encircled by a white band at the periphery.

Although the specimens which have been collected in the Hawaiian Islands appear to occur in relatively shallow water in fine sand, these terebrids are uncommonly encountered. *T. dimidiata* feeds on the enteropneust *Ptychodera flava* at Enewetak, Marshall Islands (B. A. Miller, 1970).

T. dimidiata occurs throughout the Indo-West Pacific from Mauritius to Okinawa and the Tuamotus (Demond, 1957).

Terebra felina (Dillwyn, 1817). Fig. 129 C. (Synonyms: *Terebra suffusa* Pease, 1869b; *T. tigrina* Gmelin, Tinker, 1952.) Length, 35 mm; diameter, 9 mm. *Shell:* subulate; smooth; subsutural band defined by a shallow groove; white, often with a spiral of brown spots on each whorl. *Spire:* eight or nine whorls exclusive of the protoconch; whorls more or less straight-sided; suture impressed. *Sculpture:* apical whorls with axial ribs and punctate subsutural groove; abapical whorls smooth except for the sutural groove and microscopic growth striae. *Aperture:* ovate; columella

straight with a groove below the base. *Color:* variable — white or clouded with a single row of brown spots or lines on the base of each whorl.

These terebrids live in areas of deep, coarse sand and gravel in shallow water. The animals bury in sand to a depth of several centimeters during the day, and may crawl during the night with most or all of the shell covered by sand. They feed on the deposit-feeding capitellid polychaete *Dasybranchus caducus* (Grube, 1846), extracting their prey from the deep burrows in which the worm lives by everting the labial tube (B. A. Miller, 1970).

T. felina occurs throughout the Indo-West Pacific.

Terebra funiculata Hinds, 1844. Fig. 129 G. (Synonyms: *Terebra langfordi* Pilsbry, 1921; *T. langfordi angustior* Pilsbry, 1921; *T. archimedis* Deshayes, Kay, 1967b.) Length, 41 mm; diameter, 8 mm. *Shell:* elongate, tapering; subsutural band of strong spiral cords; remainder of whorls with spiral cords and threads; buff. *Spire:* protoconch of five white or light-colored whorls, the third often inflated and distorted; whorls of teleoconch short and convex; suture impressed. *Sculpture:* subsutural band a convex cord separated from the remainder of the whorl by a wide, shallow groove, occupying about one-third of each whorl; remainder of whorls with four or more progressively smaller cords or threads crossed by fine axial striae; apical whorls with the subsutural band and subsequent spirals finely beaded. *Aperture:* ovate; columella twisted. *Color:* light yellow to buff.

Specimens are found at depths of 3 to 200 m and are especially common at depths greater than 50 m.

T. funiculata was described from the Marquesas Islands, and apparently occurs throughout the Indo-West Pacific. Shell sculpture is apparently variable. Hinds's type of *T. funiculata* has the middle of the whorls slightly constricted and smooth except for a single spiral groove; shells with strong subsutural cords resemble those of the type of Deshayes' (1859) *T. archimedis*. Forms with sculpture intermediate between the two extremes are found, however, and as the protoconchs in forms exhibiting the extremes in sculpture are similar in shape and size, only one species is recognized here.

Terebra gouldi Deshayes, 1859. Fig. 128, 129 D. Length, 58 mm; diameter, 12 mm. *Shell:* elongate, ventricose; subsutural band defined by a groove; remainder of whorls with fine axial ribs; interspaces smooth; pale buff to brown, usually banded with brown. *Spire:* protoconch of three and one-half conical whorls; whorls of teleoconch straight-sided to convex; suture impressed. *Sculpture:* smooth, oblique, fine axial ribs, the interspaces smooth and equal in diameter to the ribs; subsutural band demarcated by a deep groove. *Aperture:* ovate; base constricted and separated from the fasciole by a furrow bounded by a steep ridge. *Color:* variable — light tan in sand flats around Oahu to dark brown in deeper waters leeward of Maui (B. A. Miller, 1970); usually lineated with brown and with brown splashes on the subsutural band.

The habits of this terebrid have been extensively described by B. A. Miller (1970, 1975) and Miller and Coker (1972). The animals are common in sandy areas from slightly below mean low water to depths of more than 100 m, usually where there is little or no wave action and soft sand. They prey on the hemichordate *Ptychodera flava*, engulfing their prey with a long, radular-free proboscis. The eggs are deposited

in small capsules (1.5 mm long, .2 mm wide) on sand grains (Fig. 125 B). Egg masses of 140 capsules, each containing six to eight eggs have been recorded. The juveniles hatch through a perforation in the capsule 30 to 40 days after development begins and immediately burrow in sand. Adults appear to live for a maximum of seven to ten years. Natural predation on adults results mainly from the sand crab *Calappa hepatica* and the gastropod *Natica gualteriana*.

T. gouldi is endemic to the Hawaiian Islands. It is found from Midway to Maui, but not on Hawaii.

Terebra guttata (Röding, 1798). Fig. 127 B. (Synonyms: *Terebra sculptilis* Pease, 1869b; *T. oculata* Lamarck, Bryan, 1915.) Length, 109 mm; diameter, 17 mm. *Shell:* elongate, slender, attenuate; subsutural band noduled; orange with white nodules. *Spire:* tapering; 20 or more slightly convex whorls; suture impressed. *Sculpture:* whorls microscopically striate; subsutural band defined by a groove on apical whorls only and consisting of large, blunt nodules on the later whorls. *Aperture:* large; columella moderately twisted. *Color:* pale straw, nodules white.

These terebrids are found in localized areas of sand and rubble at depths of 2 m and more.

T. guttata is a well-known species throughout the Indo-West Pacific.

Terebra kilburni Burch, 1965. Fig. 130 A. Length, 17 mm; diameter, 3.5 mm. *Shell:* very slender; subsutural band defined by a spiral of punctations; with close-set axial ribs; cream stained with red brown in the interspaces between the ribs and with a white subsutural band. *Spire:* protoconch of three and one-half conical, glassy whorls; teleoconch of 12 straight-sided whorls; suture oblique, impressed, ledged. *Sculpture:* close-set, straight, rounded axial ribs, 19 on the last whorl 3.5 mm in diameter, ribs and interspaces of about the same diameter; interspaces with about five punctations, the apical spiral of punctae setting off a subsutural band. *Aperture:* narrowly ovate; columella and siphonal canal twisted. *Color:* ivory-white or cream lightly stained with red-brown in the interstices between the ribs, subsutural band white.

These terebrids are rare, dredged at depths of 100 m.

T. kilburni was described from Fiji.

Terebra maculata (Linnaeus, 1758). Fig. 129 J. Length, 130 mm; diameter, 37 mm. *Shell:* ventricose, solid; subsutural band defined by a spiral groove; remainder of whorls smooth; cream with two rows of axially oriented brown spots. *Spire:* protoconch of about three whorls; teleoconch of twelve or more whorls, tapering acutely toward the apex, the last whorl broad in proportion to the others; suture impressed. *Sculpture:* subsutural band defined by a spiral groove; with axial ribs on the apical whorls; abapical whorls with microscopic striae. *Aperture:* ovate; fasciole strongly developed; columella short with an oblique fold. *Color:* cream or fawn with two rows of brown maculations, the apical row of axially oriented rectangular splashes, the abapical row of smaller brown spots.

This terebrid is common, found at depths of from less than 1 m to at least 200 m. The animals feed on the capitellid polychaete *Dasybranchus caducus* (B. A. Miller,

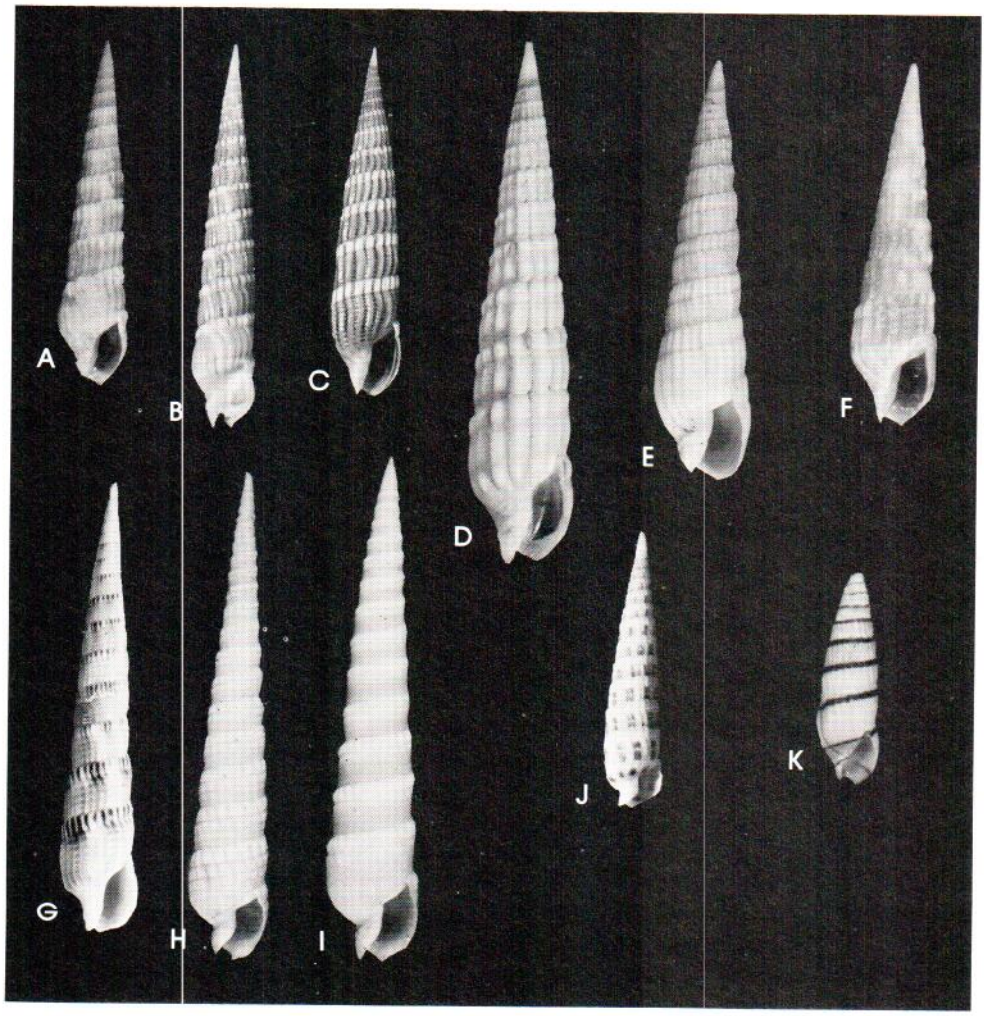


Figure 130.—**Terebridae.** A. *Terebra kilburni*, length 17 mm. B. *T. columellaris*, length 40 mm. C. *T. nebulosa*, length 32 mm. D. *T. undulata*, length 37 mm. E. *T. affinis*, length 42 mm. F. *T. rosacea*, length 18 mm. G. *T. pertusa*, length 60 mm. H. *T. babylonia*, length 45 mm. I. *T. amanda*, length 40 mm. J. *T. waikikiensis*, length 30 mm. K. *Terenolla pygmaea*, length 11 mm.

1970). The veligers hatch when one whorl is complete, add two more whorls while planktonic, and settle when the columella is 700 to 800 μm in length and three to three and one-half whorls are complete (J. B. Taylor, 1975).

This well-known species, the largest in the genus, occurs throughout the Indo-West Pacific. *T. maculata roosevelti* from Socorro Island, Mexico, is the west American subspecies (Keen, 1971).

Terebra nebulosa Sowerby, 1825. Fig. 130 C. (Synonym: *Terebra affinis* Weaver, 1960, non Gray, 1834b.) Length, 32 mm; diameter, 7.3 mm. *Shell:* elongate-cylindrical, solid; subsutural band defined by a punctate spiral groove, re-

mainder of whorl with broad, curved axial ribs, the interspaces with shallow grooves; ivory-white with orange-red blotches. *Spire:* protoconch of three and one-half whorls; whorls flat to convex, the last whorl broad and angulate. *Sculpture:* subsutural band defined by a punctate spiral groove; axial ribs rounded and moderately curved, interspaces shallow with spiral grooves. *Aperture:* ovate; columella straight, corded. *Color:* ivory-white with orange-red or dark carmine blotches, the last whorl with a white spiral about the periphery.

These shells are rarely collected, found at depths of 3 to 10 m.

T. nebulosa is distributed throughout the Indo-West Pacific.

Terebra nodularis Deshayes, 1859. Fig. 129 F. (Synonym: *Terebra textilis* Weaver, 1960 non Hinds, 1843.) Length, 37 mm; diameter, 7 mm. *Shell:* elongate; whorls convex and granular; subsutural band defined by a groove; remainder of whorls with oblique axial ribs and spiral grooves; white to buff. *Spire:* protoconch of four white, conical whorls; teleoconch of 17 or 18 whorls; sutural band convex and abapical portions of the whorls slope toward the indented suture. *Sculpture:* subsutural band defined by a groove, of two rows of prominent nodules; remainder of whorls with oblique axial ribs crossed by spiral grooves on the abapical portions. *Aperture:* narrow, ovate; columella twisted. *Color:* live-collected shells buff, beachworn specimens white.

T. nodularis is a common species at depths of from 1 to 100 m.

This species was described from the Hawaiian Islands but apparently occurs throughout the Indo-West Pacific.

Terebra pertusa (Born, 1778). Fig. 130 G. Length, 60 mm; diameter, 9 mm. *Shell:* slender, tapering; subsutural band defined by pits; with axial ribs latticed by spiral cords; cream, subsutural band brown and white. *Spire:* protoconch of four conical, cream whorls; whorls of teleoconch straight-sided; suture linear. *Sculpture:* narrow, keeled axial ribs, ribs and interspaces equal in diameter, interspaces with flat spiral cords; subsutural band distinct, set off by pits in the intercostal spaces. *Aperture:* ovate; base constricted; columella barely twisted. *Color:* white or cream, intercostal spaces on the subsutural band dark brown.

These terebrids are found to depths of 160 m. The shells are variable with respect to the development of spiral threads in the interspaces between the ribs.

T. pertusa is distributed throughout the Indo-West Pacific.

Terebra rosacea Pease, 1869b. Fig. 130 F. Length, 18 mm; diameter, 4 mm. *Shell:* slender, glossy; subsutural band defined by a deep spiral groove; remainder of whorls axially ribbed with sharp keels, interspaces with low spiral cords; creamy red. *Spire:* protoconch of four white, conical whorls; whorls of teleoconch straight-sided; suture constricted and oblique. *Sculpture:* subsutural band defined by a deep spiral groove dissecting elevated, keeled axial ribs and forming nodules; remainder of whorl with keeled axial ribs, the interspaces equal in diameter to the ribs and crossed by flat cords. *Aperture:* narrow, oblong, small; inner lip not raised; base constricted. *Color:* columella, aperture, and spire deep rose; subsutural band sometimes with white ribs.

Shells are abundant at depths from 50 to 200 m.

T. rosacea was described from the Hawaiian Islands. The angulate axial ribs, wide interspaces, and smooth subsutural band distinguish these shells from those of *T. columellaris*.

Terebra subulata (Linnaeus, 1767). Fig. 127 E. Length, 100 mm; diameter, 15 mm. *Shell:* slender, tapering; smooth with a subsutural groove; cream with two spirals of rectangular dark brown blotches on each whorl. *Spire:* protoconch of three and one-half conical, brown whorls; apical whorls of teleoconch axially plicate, whorls flat, convexly rounded at the suture. *Sculpture:* apical whorls with fine axial ribs, later whorls smooth except for a spiral groove marking the subsutural band, the groove often obsolete on abapical whorls. *Aperture:* subovate; columella undulate; siphonal canal recurved. *Color:* cream with two rows of angular blotches on each whorl, three on the last square or rectangular brown blotches, three spirals on the last whorl, two on the others.

This species is rarely found in Hawaiian waters and only two or three specimens have been collected in shallow water at depths of 3 m.

T. subulata is distributed throughout the Indo-West Pacific.

These shells are distinguished from those of *T. areolata* by their short, undivided whorls which are roundly angulate at the suture.

Terebra thaanumi Pilsbry, 1921. Fig. 129 E. Length, 56 mm; diameter, 12 mm. *Shell:* ventricose, whorls convex; finely axially ribbed; interspaces smooth; sutural band defined by a groove; cinnamon-brown. *Spire:* protoconch of about three conical whorls; teleoconch of 14 or 15 short, convex whorls; suture impressed. *Sculpture:* smooth, oblique, fine axial ribs, the interspaces about equal in diameter to the ribs; sutural band marked by a smooth groove. *Aperture:* ovate; columella twisted. *Color:* cinnamon brown or russet, not marked with darker brown as in the shells of *T. gouldi*.

This terebrid occurs at depths of from 40 to 80 m.

T. thaanumi was described from the Hawaiian Islands. Pilsbry distinguished the shells from those of *T. gouldi* by the shorter, more convex whorls and the chestnut to cinnamon-brown color.

Terebra undulata Gray, 1834b. Fig. 130 D. (Synonym: *Terebra flavofasciata* Pilsbry, 1921; *T. propinqua* Pease, Weaver, 1960.) Length, 37 mm; diameter, 8 mm. *Shell:* elongate, solid; subsutural band defined by a groove; remainder of whorls with well-developed, keeled axial ribs, interspaces with spiral cords; orange-red to orange-yellow. *Spire:* protoconch of four conical, white whorls; whorls of teleoconch flat-sided; suture impressed. *Sculpture:* straight, keeled axial ribs, 18 on the last whorl 8 mm in diameter, separated by spirally corded interspaces equal in diameter to the ribs; subsutural band defined by a spiral groove. *Aperture:* ovate; base constricted. *Color:* orange-red or orange-yellow, banded with white on the subsutural nodules.

These terebrids are found at depths of from 3 to 160 m. The veligers hatch when one and one-half whorls are complete, add three whorls while in the plankton, and settle at lengths of 1.15 to 1.25 mm when five whorls are complete (J. B. Taylor, 1975).

T. undulata was described from the Philippines and is distributed throughout the Indo-West Pacific from the Persian Gulf to Micronesia and Polynesia. The shells are distinguished from those of *T. columellaris* by their yellow color, wider shape, and straighter axial ribs.

Terebra waikikiensis Pilsbry, 1921. Fig. 130 J. Length, 30 mm; diameter, 7 mm. *Shell:* slender, elongate; subsutural band defined by a spiral of punctures, noduled; remainder of whorls with close-set axial ribs and spiral striae; white with spirals of chestnut spots. *Spire:* protoconch of four and one-half white whorls; whorls of teleoconch somewhat concave above the suture; last whorl convex. *Sculpture:* subsutural band defined by punctations, of elevated axial nodules, smooth in the interspaces; remainder of whorls with obsolete axial ribs which are close-set and slender, and with spiral striae. *Aperture:* small, ovate; siphonal canal recurved; columella with a fold. *Color:* white, with three axially arranged spirals of pale chestnut spots on the last whorl, two on the apical whorls.

These terebrids are found at depths of from 50 to 200 m.

T. waikikiensis was described from the Hawaiian Islands.

Terenolla pygmaea (Hinds, 1844). Fig. 130 K. Length, 11 mm; diameter, 3 mm. *Shell:* subulate, solid; with fine, oblique axial keels; cream, suture delineated by a dark brown spiral thread. *Spire:* six or seven whorls plus the protoconch; whorls somewhat turreted at the suture. *Sculpture:* numerous, fine, oblique axial keels, the interspaces of slightly lesser diameter and smooth. *Aperture:* ovate, siphonal canal short, blunt. *Color:* cream, with a thin brown spiral at each suture and one around the base; outer lip margined with brown.

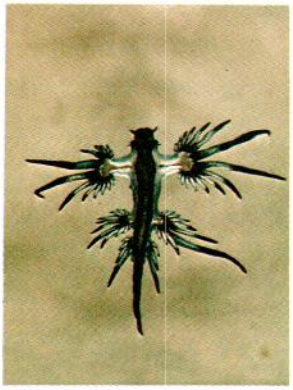
This species occurs in tide pools and at depths to 20 m.

T. pygmaea was described from the Strait of Malacca, and is apparently widely distributed in the Indo-West Pacific.

Additional Records

Three species of terebrids are rare or found only in deep water in Hawaii: *Hastula australis* (E. A. Smith, 1873), with a light-colored shell differentiated by a dark base (Salisbury, 1978); *Terebra amoena* Deshayes, 1859, the shells of which are similar to those of *T. pertusa* but which are distinguished by their stouter form and wider, more pronounced ribs (Salisbury, 1978); and *T. triseriata* Gray, 1834, with a slender shell, dredged by the *Pele* at depths of about 50 m. Additional species have been recorded, but the records are either unconfirmed or erroneous: *Hastula anomala* (Gray, 1834b), the shells of which superficially resemble those of *H. inconstans* but which are distinguished by a single row of punctations (Burch, 1965); *Terebra cancellata* Quoy and Gaimard, 1832 (Burch, 1965; Cernohorsky and Jennings, 1966, as *T. succincta* Gmelin, 1791); *T. costellifera* Pease, 1869b (not identifiable from the original description); *T. dislocata* Say (Mant, 1923; a west American species); *T. marmorata* Deshayes, 1859 (Burch, 1965, at depths of 10 m off Kihei, Maui); *T. polygyrata* Deshayes (Weaver, 1960); *T. sandwicensis* Sowerby, 1844 (*nomen nudum*); *T. senegalensis* Lamarck (Kaicher, 1956); and *T. tricolor* Sowerby, 1825 (Burch, 1965, at depths of 10 m off Maui).

A



B

C

D

E

F

Figure 131.—Opisthobranch life styles. A. The cephalaspid *Hydatina physis* and its egg mass. B. The pelagic aeolid *Glaucus atlanticus*. C. The sea hares *Aplysia parvula* in a copulation chain. D. The pleurobranchid *Euselenops luniceps* in sand. E. A predatory dorid, *Gymnodoris okinawae*. F. Two dorids, *Doriopsis pecten*, with yellow egg mass and the blue sponge on which the dorids feed. (A. by S. A. Reed.)

Subclass OPISTHOBRANCHIA

The opisthobranchs are a relatively small group of gastropods, with an estimated 1,000 (Hyman, 1967) to 2,500 (Solem, 1974) species. In form, color, and habits they are among the most extravagantly diversified of all gastropods, albeit they are restricted almost entirely to the marine environment.

In the opisthobranchs the typical gastropod organization of head-foot and spiral, univalve shell enclosing a mantle cavity and visceral hump is exhibited in only two, perhaps primitive, groups: the Pyramidellacea and the Cephalaspidea. In each of the superfamilies, except for the pyramidellids, there is a trend toward a reduction of the spiral shell, the trend culminating in the Nudibranchia where a spiral shell occurs only in the larval stage.

The features by which most gastropods are recognized are variously modified in the opisthobranchs. At the head end there are from one to three tentacular projections: one pair associated with the mouth, forming outgrowths or oral lappets; a second pair, the cephalic tentacles, lying behind the mouth; and a posterior pair, the rhinophores, found posteriorly behind the head. The eyes, rather than being mounted on tentacles, are sunk into the epidermis. The mantle in the pyramidellids and cephalaspids with a well-developed shell is small and inconspicuous. In the Anaspidea and Nudibranchia with a reduced shell or no shell, the dorsum or notum is soft and variously sculptured, often with outgrowths in the form of papillae or cerata, some of which bear a branch of the digestive gland, and there are often gland cells which secrete acid or other toxic substances (Edmunds, 1966). A characteristic feature of the foot is the development of lateral expansions, called parapodia. In the cephalaspids the parapodia are associated with a burrowing habit; in the aplysiids the parapodia may function in swimming.

The diet of opisthobranchs is almost as varied as is their body form. A radula is present in some, but it is not referable to definite types as it is in the prosobranchs. Opisthobranchs are both herbivorous and carnivorous, and many are very specific in their feeding habits. Some herbivorous sacoglossans are restricted in their diet to particular species of siphonous algae; among the carnivorous nudibranchs, grazing, sponge-feeding dorids and the coelenterate-feeding aeolids are equally specific in their prey.

Associated with the diet of some opisthobranchs are several unique features. Some aeolids have the ability to incorporate nematocysts from their coelenterate prey into the dorsal integument and to explode the nematocysts when they are disturbed. Some of the sacoglossans accommodate chloroplasts from their algal food in the cells of the digestive gland, the chloroplasts remaining functional and presumably contributing to the nutrition of the animals for varying periods of time. In *Melibe* zooxanthellae are found in the dorsal projections.

Opisthobranchs are hermaphroditic, with a large ovotestis and complicated series of male and female ducts which converge on the right side of the body. The egg masses are conspicuous and characteristic of different groups. Hurst (1967) has described four basic types of egg masses, three of which are common among Hawaiian opisthobranchs: the ovoid, jelly-filled sacs of *Atys* and *Philinopsis* (Fig. 134 A-C); the ribbonlike mass with one edge attached to the substrate, as is characteristic of *Hydatina physis, Umbraculum sinicum* (Fig. 134 D, I) and most dorids; and the cylindrical, capsule-filled cord attached along one side as found in many aeolids (Fig. 156 F). A fifth type, cylindrical coils attached to the substrate produced by *Bulla, Bullina, Haminoea* (Fig. 134 E-H), and many sacoglossans might also be identified.

Most opisthobranchs hatch as swimming veliger larvae with a thin, transparent shell; a ciliated, bilobed velum; and a small foot with an operculum. The veligers may exhibit marked specificity to the substrate: larvae of *Phestilla sibogae,* for example, metamorphose only in the presence of the coral *Porites* (Hadfield and Karlson, 1969). Direct development is known in only one Hawaiian opisthobranch, *Okadaia elegans* (Doridacea, Vayssiereidae) which emerges from the egg as a miniature adult (Baba, 1937).

Perhaps associated with their soft bodies and specialized feeding habits is the tendency among some opisthobranchs for a "boom and bust" type of life history. Not only is reproductive potential enormous (an estimated 500,000 eggs have been counted in a single egg mass of *Dendrodoris nigra),* but generation time may be on the order of weeks. In *Phestilla sibogae* in Hawaii, generation time is on the order of 40 days (Hadfield, 1972) and in *Aplysia juliana* it is 70 days (Dunlap, pers. comm.). During the period of their reproductive activity, opisthobranchs may grow to relatively enormous size, but apparently often within less than a year, they stop feeding, shrink in size, and die.

Family **Pyramidellidae**

Pyramidellid shells are characterized by their heterostrophic protoconchs, a feature which, with some characteristics of the digestive and reproductive systems, has led to their inclusion among the opisthobranchs (Fretter and Graham, 1962). There are two types of protoconch: one coiled in a helicoid spiral, usually with a small, closely coiled, centrally situated nucleus; the other coiled in a planorboid spiral of fewer volutions and with the nucleus larger and nearer one side. Shell form, size and sculpture range widely: shells are ovate to elongate-cylindrical, from 2 to 40 mm in length in Hawaii, and smooth or sculptured with microscopic striae or macroscopic keels, ribs or nodules.

Pyramidellid systematics are unsatisfactory. Laseron (1959) recognizes three subfamilies based on shell characters (the Pyramidellinae with two or three columellar folds, the Odostominae with one columellar fold, and the Turbonillinae which lack columellar folds). I have merely arranged the genera alphabetically, and I have followed Laws (1937) and Laseron (1959) in the use of full genera rather than subgenera.

In habit many pyramidellids are ectoparasitic on polychaete worms, bivalves and other gastropods. In the Hawaiian Islands several species are common in shallow water in tide pools and on fringing reefs, and three species may be locally abundant in

nutrient rich (eutrophic) waters such as in Pearl Harbor and Kaneohe Bay, Oahu, where they comprise a dominant component of the micromolluscan assemblages. The pyramidellids in these areas are presumably parasitic on various sessile fouling organisms such as sponges and bivalves.

One pyramidellid genus, *Nesiodostomia,* may be endemic to the Hawaiian Islands (Corgan, 1972).

Evalea peasei (Dautzenberg and Bouge, 1933). Fig. 132 A. (Synonyms: *Odostomia eclecta* Pilsbry, 1918; *O. eclecta nematoderma* Pilsbry, 1918.) Length, 4 mm; diameter, 1 mm. *Shell:* conic-elongate; microscopically densely striated; white. *Spire:* protoconch heterostrophic, of one bulbous whorl; teleoconch of six slightly convex whorls separated by an oblique, channeled suture. *Sculpture:* dense, microscopic axial and spiral striae. *Aperture:* ovate, outer lip thin; with a single columellar fold. *Color:* white.

These pyramidellids are found in tide pools, sometimes beneath the valves of *Isognomon perna,* and occasional shells occur in sediments to depths of 26 m.

E. peasei occurs through the Indo-West Pacific, from the Cocos-Keeling Islands to the Tuamotus.

Evalea waikikiensis (Pilsbry, 1918). Fig. 132 B. (Synonyms: *Odostomia gracilis* Pease, 1868b, non Philippi, 1836; *O. haleiwensis* Pilsbry, 1918; *O. hiloensis* Pilsbry, 1944.) Length, 2.8 mm; diameter, 1 mm. *Shell:* conic-ovate, thin; with low axial ribs and fine spiral striae; white. *Spire:* protoconch heterostrophic, of one and one-half emergent whorls; teleoconch of five convex, inflated whorls; suture impressed. *Sculpture:* low axial ribs weakening at the periphery of the last whorl and fine spiral striae throughout. *Aperture:* ovate; columella with an immersed fold. *Color:* white.

Shells of *E. waikikiensis* are less commonly found than are those of *E. peasei,* but they are predominantly shallow-water forms occurring in tide pools and on fringing reefs.

E. waikikiensis was described from the Hawaiian Islands.

Herviera gliriella (Melvill and Standen, 1896). Fig. 132 C. Length, 1.6 mm; diameter, 0.7 mm. *Shell:* cylindric-ovate; with straight axial ribs; brown or purple-red. *Spire:* protoconch heterostrophic, partly immersed; teleoconch of three or four straight-sided whorls separated by a distinct, deep suture. *Sculpture:* straight, rounded axial ribs, the interspaces of slightly lesser diameter and smooth. *Aperture:* ovate; columella with a low fold. *Color:* variable — golden brown to purple-red.

These pyramidellids are common in tide pools and on fringing reefs, and shells are found in sediments to depths of 65 m.

H. gliriella was described from Lifu and also occurs in the Line Islands.

Herviera patricia Pilsbry, 1918. Fig. 132 D. (Synonyms: *Odostomia patricia* var. *rosa* Pilsbry, 1918; *O. patricia* var. *rhodocephala* Pilsbry, 1918.) Length, 1.6 mm; diameter, 0.7 mm. *Shell:* cylindric-ovate; with straight axial ribs; white with spiral brown thread. *Spire:* protoconch of a single in-turned whorl; teleoconch of three

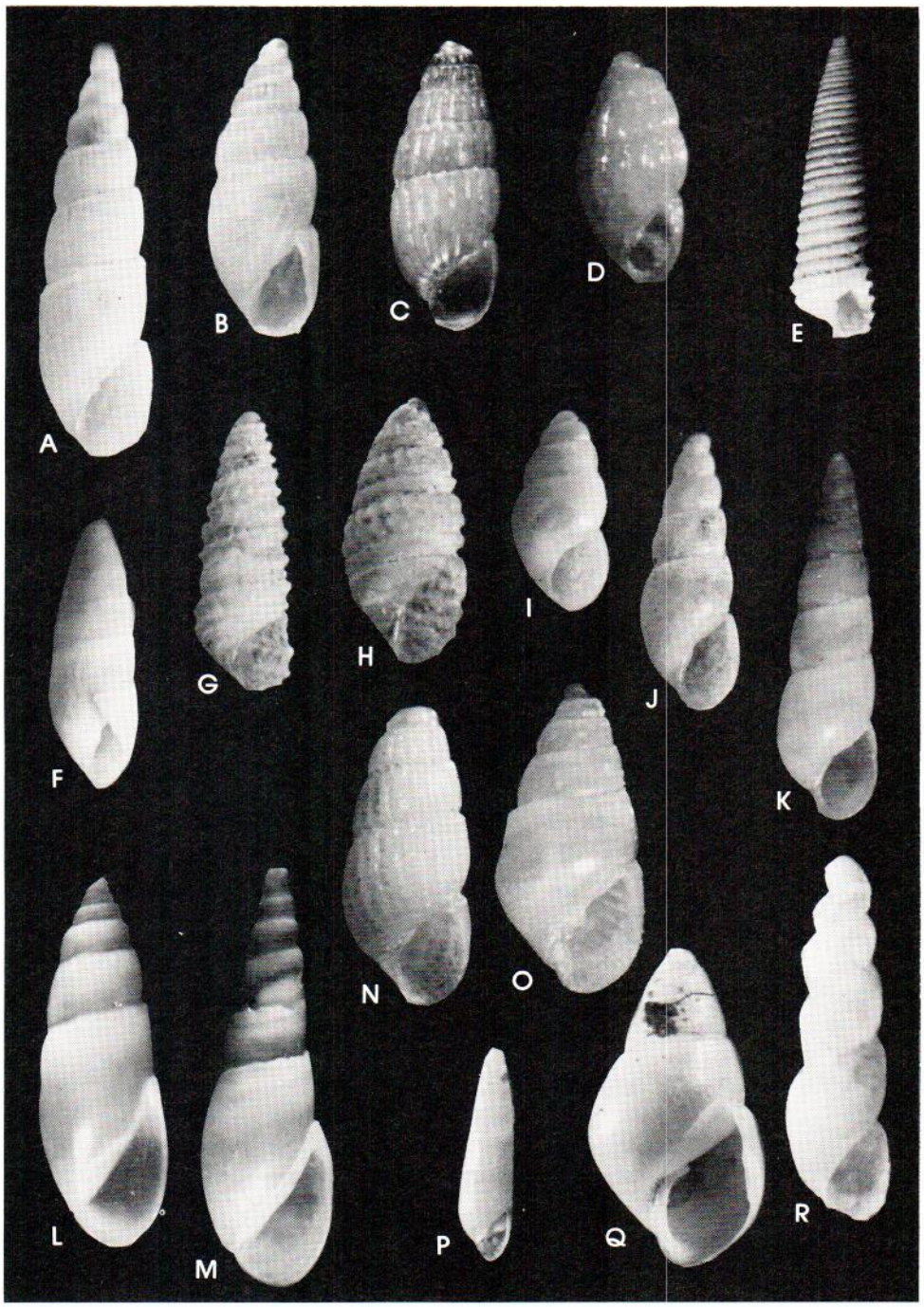


Figure 132.—**Pyramidellidae.** A. *Evalea peasei*, length 4 mm. B. *E. waikikiensis*, length 3 mm. C. *Herviera gliriella*, length 2 mm. D. *H. patricia*, length 1.6 mm. E. *Hinemoa indica*, length 5 mm. F. *Odostomia rosacea*, length 6 mm. G. *Miralda paulbartschi*, length 2.5 mm. H. *M. scopulorum*, length 1.5 mm. I. *Odostomia oxia*, length 2 mm. J. *O. gulicki*, length 3 mm. K. *Syrnola lacteola*, length 8 mm. L. *Nesiodostomia quinta*, length 7 mm. M. *N. montforti*, length 4 mm. N. *Pyrgulina oodes*, length 1.5 mm. O. *Odostomia stearnsiella*, length 2 mm. P. *Nesiodostomia quarta*, length 2 mm. Q. *Odostomia margarita*, length 1.5 mm (holotype, Academy of Natural Sciences of Philadelphia). R. *Koloonella hawaiiensis*, length 1.25 mm (holotype).

straight-sided whorls separated by a distinct, deep suture. *Sculpture:* straight, rounded axial ribs, the interspaces of slightly lesser diameter and smooth. *Aperture:* ovate; columella with a single low fold. *Color:* white spirally threaded with brown.

Shells are occasionally found in tide pools and on reefs, and in sediments to depths of 65 m.

This species was described from the Hawaiian Islands.

Hinemoa indica (Melvill, 1896). Fig. 132 E. (Synonym: *Odostomia pupu* Pilsbry, 1918.) Length, to 5 mm; diameter, to 3 mm. *Shell:* conic-elongate; with smooth spiral keels and fine, threadlike axials; white. *Spire:* protoconch heterostrophic, immersed except for the tip; teleoconch of up to eight somewhat inflated whorls; suture not distinct. *Sculpture:* with three raised, smooth, spiral keels on the apical whorls, six on the last whorl, the interspaces with fine axial threads. *Aperture:* ovate, oblique; columella with a single low fold. *Color:* white; transparent in juvenile shells.

These pyramidellids are common in tide pools and on fringing reefs, and abundant in shallow, nutrient rich waters such as in Pearl Harbor and south Kaneohe Bay, Oahu. Tide pool specimens are usually small (2 mm in length); those from Pearl Harbor and Kaneohe Bay may reach 8 mm in length.

H. indica was described from the Indian Ocean, and also occurs in Ceylon and Indo-China (Dautzenberg and Fischer, 1906).

Koloonella hawaiiensis Kay, new species. Fig. 132 R. Length, 1.25 mm; diameter, 0.25 mm. *Shell:* elongate, narrow, nearly cylindrical; thin and fragile; smooth; transparent, white. *Spire:* protoconch heterostrophic, exsert, of one and one-half whorls; teleoconch of five slight convex whorls distinctly constricted at the suture. *Sculpture:* surface smooth and shiny, with microscopic growth striae; texture transparent. *Aperture:* small, ovate, base of outer lip projecting. *Color:* transparent, white.

These shells are found in sediments at depths of from 3 to 60 m, but they are rare, perhaps because of their fragile texture.

Type locality: Honolulu Harbor, Oahu, in sediments at a depth of about 43 m. *Holotype:* Bernice P. Bishop Museum, No. 9902. *Paratypes:* Australian Museum, British Museum (Natural History), U. S. National Museum.

The genus was introduced by Laseron (1959) for elongate, thin, translucent shells without sculpture, with a simple aperture and no columellar folds, and generally with an exsert protoconch. Four species were included in the genus, two described by Laseron from Australia and New Guinea and two previously described by Watson (1886) as *Odostomia*. The Hawaiian shells most nearly resemble those of *K. tenuis* Laseron, 1959, from Port Moresby, New Guinea, but they are distinguished by their smaller size (1.25 vs. 2.5 mm), lesser number of whorls (five rather than seven), and the slightly wider whorls proportionate to the length of the shell.

Miralda paulbartschi Pilsbry, 1918. Fig. 132 G. Length, 2.5 mm; diameter, 0.95 mm. *Shell:* conic-elongate, slender; with noduled spiral keels; white. *Spire:* protoconch heterostrophic, of a single low whorl; teleoconch of five rather flat-sided whorls, suture indistinct. *Sculpture:* three spiral keels on each whorl, the apical smooth, the middle keel with axially elongate nodules, and the third with small granules; base with

a smooth spiral cord. *Aperture:* oblique, outer lip with a turridlike sinus; columella narrow with a small fold. *Color:* white.

These pyramidellids are common in tide pools and on benches; shells are rarely found in sediments to depths of 40 m.

This species was described from the Hawaiian Islands. It is distinguished from *M. scopulorum* by the axially elongate row of granules and its predominantly shallow-water habitat.

Miralda scopulorum Watson, 1886. Fig. 132 H. (Synonym: *Odostomia syrtites* Pilsbry, 1918.) Length, 1.5 mm; diameter, 0.95 mm. *Shell:* conic-ovate; with two rows of spiral granules and a third smooth keel on each whorl; white. *Spire:* protoconch heterostrophic, barely emergent; teleoconch of three or four barely convex whorls; suture indistinct. *Sculpture:* two apical rows of spiral granules and a third smooth keel on each whorl; base with two spiral keels and axial threads. *Aperture:* ovate, oblique; columella concave, with a single strong fold. *Color:* white.

Shells of *M. scopulorum* are occasionally found on fringing reefs but are more common at depths of 8 to 40 m.

M. scopulorum was described from the Torres Straits. The shells Pilsbry distinguished as *Odostomia syrtites* fall well within the range of variation of a single species.

Nesiodostomia montforti Corgan, 1972. Fig. 132 M. (Synonym: *Odostomia (Nesiodostomia) secunda* Pilsbry, 1918, non Boettger, 1907.) Length, 4 mm; diameter, 1 mm. *Shell:* cylindrical-elongate; glossy brown. *Spire:* protoconch heterostrophic, partly immersed; teleoconch of five somewhat flat-sided whorls with deeply impressed suture. *Sculpture:* microscopic axial and spiral striae only. *Aperture:* narrowly pyriform; outer lip thin. *Color:* slightly transparent, brown.

Pilsbry described the species from a shell found at Mokapu Point, Oahu; it is apparently extremely rare, and is endemic to the Hawaiian Islands.

N. montforti is distinguished from *N. quinta* by its smaller size and different proportions.

Nesiodostomia quarta (Pilsbry, 1918). Fig. 132 P. Length, 3.4 mm; diameter, 0.9 mm. *Shell:* cylindric-elongate; smooth and glossy; cinnamon-rufous. *Spire:* protoconch heterostrophic, partially immersed; teleoconch of five flat-sided whorls separated by a narrowly impressed suture. *Sculpture:* microscopic axial and spiral striae only. *Aperture:* subpyriform; outer lip thin and arching forward; parietal margin callused. *Color:* cinnamon-rufous.

N. quarta is rarely found; occasional shells have been dredged at depths of about 10 m.

This species is endemic to the Hawaiian Islands. It is distinguished from the other species of *Nesiodostomia* by its slender form and smaller size.

Nesiodostomia quinta (Pilsbry, 1944). Fig. 132 L. (Synonyms: *Odostomia prima* Pilsbry, 1918, non Boettger, 1907; *O. tertia* Pilsbry, 1918.) Length, 7 mm; diameter,

2 mm. *Shell:* cylindric-elongate; smooth and glossy; cream spirally banded with brown. *Spire:* protoconch heterostrophic, low spired, of two or three partly immersed whorls; teleoconch of five to seven flat-sided, slightly inflated whorls separated by a deeply impressed suture. *Sculpture:* microscopic axial and spiral striae only. *Aperture:* pyriform, narrow; outer lip thin and arching forward; columella with an internal fold not visible from the aperture; parietal region often with a callosity. *Color:* variable — white or cream with a broad gray zone beneath the suture and a broad tawny band across the periphery of the last whorl, all cream or tawny.

These shells are locally common in beach drift along the shores of the southern coast of Kauai and the southwestern coast of Oahu, but nothing is known of the habits of the living animals.

N. quinta is endemic to the Hawaiian Islands. Corgan (1972) suggests that the holotype and only known specimen of *Odostomia tertia* is a diseased specimen, an interpretation with which I concur.

Odostomia gulicki Pilsbry, 1918. Fig. 132 J. Length, 2.2 mm; diameter, 0.85 mm. *Shell:* conic-ovate, slender, apex obtuse; columella with one fold; smooth; white. *Spire:* protoconch of a single smooth, partially immersed whorl; teleoconch of three or four inflated whorls; suture deeply impressed. *Sculpture:* smooth except for microscopic growth striae. *Aperture:* broadly oval, oblique; columellar fold weak, sometimes not distinguishable. *Color:* white.

These shells are occasionally found in beach drift, but nothing is known of the habits of the living animals.

O. gulicki was described from the Hawaiian Islands.

Odostomia margarita Pilsbry, 1944. Fig. 132 Q. Length, 4 mm; diameter, 2 mm. *Shell:* conic-ovate, spire tapered; smooth; white. *Spire:* protoconch of one emergent whorl; teleoconch of five barely inflated whorls, the last the largest and convex; suture deeply impressed. *Sculpture:* microscopic spiral growth striae only. *Aperture:* ovate; columella concave, fold strong. *Color:* glistening white.

Shells are occasionally found in sediments at depths of about 3 m.

O. margarita was described from the Hawaiian Islands.

Odostomia oxia Watson, 1886. Fig. 132 I. Length, 2 mm; diameter, 0.75 mm. *Shell:* conic-ovate, apex obtuse; columella with one fold; smooth; white. *Spire:* protoconch of one emergent whorl; teleoconch of five inflated whorls; suture deeply impressed. *Sculpture:* smooth except for microscopic growth striae. *Aperture:* broadly oval, oblique; columellar fold obvious. *Color:* white.

Occasional shells are found in beach drift and in sediments to depths of 10 m.

O. oxia was described from Cape York, Australia. The shells are distinguished from those of *O. gulicki* by their shorter and more ovate form.

Odostomia rosacea Pease, 1868b. Fig. 132 F. Length, 6 mm; diameter, 2 mm. *Shell:* conic-elongate; apex attenuate; smooth; rosy pink. *Spire:* protoconch hetero-

strophic, emergent; teleoconch of about seven rather straight-sided whorls; suture impressed. *Sculpture:* smooth and glossy with microscopic growth striae only. *Aperture:* ovate; columella arcuate. *Color:* rosy pink.

Shells are rare, found in beach drift on the northern beaches of Kauai.

O. rosacea was described from the Tuamotus.

Odostomia stearnsiella Pilsbry, 1918. Fig. 132 O. (Synonyms: *Odostomia monaulax* Pilsbry, 1918; *O. hiloensis* Pilsbry, 1921; *O. kahoolawensis* Pilsbry, 1944.) Length, 2 mm; diameter, 1 mm. *Shell:* conic-ovate; solid; with fine spiral striae; white. *Spire:* protoconch heterostrophic, partly immersed; teleoconch of five convex whorls; suture impressed. *Sculpture:* narrow spiral striae, usually four on the last whorl, which cut broad bands across the whorls, the striae encircling all but the periphery of the last whorl; base with about six weak spiral threads. *Aperture:* ovate; columella with a strong fold. *Color:* white.

These pyramidellids are common on reefs, less common in tide pools, and only occasionally found in sediments to depths of 40 m.

O. stearnsiella was described from the Hawaiian Islands. Pilsbry's types of *O. monaulax, O. hiloensis,* and *O. kahoolawensis* appear to be only beachworn variants of *O. stearnsiella.*

Otopleura mitralis A. Adams, 1854d. Fig. 133 C. Length, 15 mm; diameter, 7 mm. *Shell:* ovate, inflated; columella with three plaits; axially ribbed and spirally corded; white. *Spire:* protoconch heterostrophic; teleoconch of ten straight-sided, slightly inflated whorls; suture linear, crenulated by the axial sculpture. *Sculpture:* straight, smooth, convex axial ribs reaching the length of each whorl including the last; interspaces subequal and crossed by concave spiral cords. *Aperture:* ovate, outer lip wrinkled, thin; columella with three sharp plaits, the apical the largest and some distance away from the other two; base narrowly umbilicate. *Color:* white, occasionally with a few splashes of brown.

These pyramidellids are sand-dwellers, found on fringing reefs and in subtidal coral communities at depths to about 10 m. Shells are common in beach drift.

O. mitralis occurs throughout the Indo-West Pacific, from the Red Sea to Hawaii. In Mozambique this species is associated with the enteropneust, *Ptychodera flava* (MacNae and Kalk, 1958). The Hawaiian shells differ from those found elsewhere in the Pacific in that they lack brown shoulder streaks.

Pyramidella dolabrata (Linnaeus, 1758). Fig. 133 A. (Synonym: *Pyramidella terebellum* Müller, Edmondson, 1933.) Length, 20 mm; diameter, 10 mm. *Shell:* conical, high-spired; columella with three folds; smooth and polished; white with spiral brown threads. *Spire:* protoconch heterostrophic, of one and one-half whorls; teleoconch of eight to ten slightly inflated whorls; suture grooved. *Sculpture:* smooth and polished with microscopic growth striae only. *Aperture:* ovate, outer lip thin; columella straight with three plications; base with narrow, deep umbilicus. *Color:* white spirally threaded with brown, two threads on the apical whorls, three on the last whorl.

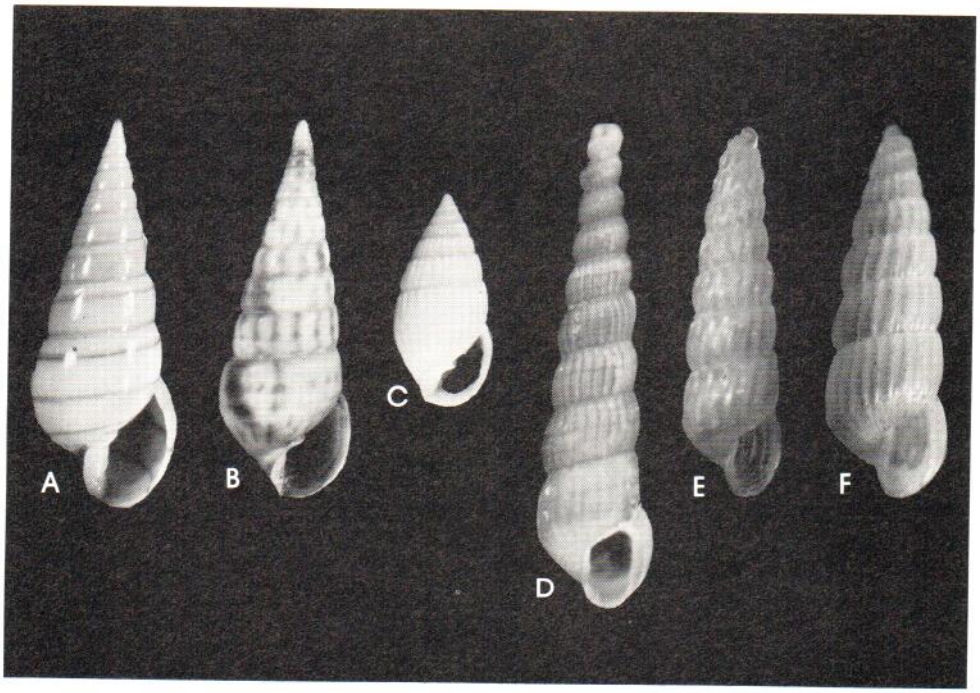


Figure 133.—**Pyramidellidae.** A. *Pyramidella dolabrata*, length 20 mm. B. *P. sulcata*, length 15 mm. C. *Otopleura mitralis*, length 15 mm. D. *Turbonilla cornelliana*, length 19 mm. E. *T. thaanumi*, length 2 mm. F. *T. lirata*, length 3 mm.

These pyramidellids are found in sand at depths of 3 to 10 m.

P. dolabrata occurs in southeast Florida, the West Indies, along the coast of Africa, and apparently throughout the Indo-West Pacific. Although the Pacific shells are distinguished as *P. terebelloides* (A. Adams, 1854d) by Habe (1964) and *P. terebellum* (Müller, 1774) by Cernohorsky (1972a), there seem to be no consistent differences between the Atlantic and Pacific shells and the species is here considered circumtropical. MacNae and Kalk (1958) record *P. dolabrata* living with the enteropneust *Ptychodera flava* in Mozambique.

Pyramidella sulcata A. Adams, 1854d. Fig. 133 B. Length, 16 mm; diameter, 10 mm. *Shell:* conical, high-spired; polished; columella with three folds; ivory lineated and spotted with brown. *Spire:* protoconch heterostrophic, of two whorls; teleoconch of more than ten whorls, the whorls slightly convex; suture channeled. *Sculpture:* smooth and polished, with microscopic growth striae only. *Aperture:* ovate; outer lip thin; columella with a large apical plait and two smaller abapical plaits; base nonumbilicate. *Color:* ivory lineated and spotted with brown.

These pyramidellids occur in sand at depths of 12 to 100 m.

P. sulcata was described from Tahiti and occurs throughout the Indo-West Pacific, and as far north as the Amami Island (Kira, 1962) in the Pacific.

Pyrgulina oodes (Watson, 1886). Fig. 132 N. Length, 1.5 mm; diameter, 0.75 mm. *Shell:* ovate; with axial ribs and fine spiral striae in the interspaces; white. *Spire:* protoconch heterostrophic, barely emergent; teleoconch of three to five convex whorls separated by a distinct, impressed suture. *Sculpture:* strong axial ribs which extend to the base of the last whorl separated by interspaces of about equal diameter, the interspaces marked by fine spiral striae producing a ladderlike effect. *Aperture:* subovate; outer lip thin; with a single columellar fold. *Color:* white.

P. oodes is common in tide pools and on reefs and in sediments to depths of 65 m. It is the dominant pyramidellid in micromolluscan assemblages from nutrient-rich waters such as Pearl Harbor and south Kaneohe Bay, Oahu.

P. oodes was described from Flinders Passage, northwestern Australia. It also occurs at Enewetak, Marshall Islands.

Syrnola lacteola (Preston, 1904). Fig. 132 K. (Synonyms: *Turbonilla (Evaletta) elizabethae* Pilsbry, 1918; *T. laysanensis* Pilsbry, 1918.) Length, 8 mm; diameter, 1 mm. *Shell:* conic-elongate; slender; smooth; white, apex pinkish-brown. *Spire:* protoconch heterostrophic, of one and one-half barely emergent whorls; teleoconch of nine flat-sided whorls; suture deep, oblique, channeled. *Sculpture:* smooth in most shells but dense microscopic striae visible in thin shells. *Aperture:* ovate; columellar fold low. *Color:* white, with a faint gray subsutural band; apical whorls pinkish brown. Juvenile shells may be all pink or brown with a darker brown subsutural band.

These shells are locally abundant in beach drift along the southern shore of Kauai and the southwest shore of Oahu, but nothing is known of the habits of the living animals.

S. lacteola was described from Ceylon and appears to be widely distributed in the Indo-West Pacific.

Turbonilla lirata (A. Adams, 1855e). Fig. 133 F. (Synonyms: *Turbonilla kahoolawensis* Pilsbry, 1918; *T. kauaiensis* Pilsbry, 1918; *T. oblectamentum* Pilsbry, 1918.) Length, 3 mm; diameter, 0.8 mm. *Shell:* conic-elongate; slender; columella without plaits; with rounded, oblique axial ribs extending to base of last whorl; white. *Spire:* protoconch heterostrophic, of one and one-half emergent whorls; teleoconch of five to seven whorls; suture deeply impressed, almost channeled, coronated by the sculpture. *Sculpture:* straight, rounded to slightly keeled axial ribs, about 24 on the next-to-the-last whorl, equal in diameter to the smooth interspaces and extending to base of last whorl but becoming weaker. *Aperture:* ovate; columella thick, smooth, straight. *Color:* white.

This species is common on fringing reefs, especially on the north shore of Kauai, and shells are occasionally found in sediments to depths of 40 m.

T. lirata was described from Japan.

Turbonilla thaanumi Pilsbry and Vanatta, 1908. Fig. 133 E. Length, 2 mm; diameter, 1 mm. *Shell:* conic-elongate, slender; columella without plaits; with curved axial ribs; white. *Spire:* protoconch heterostrophic, of one and one-half emergent whorls; teleoconch of eight slightly convex whorls; suture deep, oblique, crenulated

by the axial ribs. *Sculpture:* fine axial ribs, about 18 on the last whorl, the ribs running over the periphery of the last whorl and becoming barely visible on the base; interspaces smooth and about equal in diameter to the ribs. *Color:* transparent.

These shells are occasionally found in beach drift; living animals have been collected in the byssus of *Isognomon perna*.

T. thaanumi was described from the Hawaiian Islands.

Turbonilla (Mormula) cornelliana (Newcomb, 1870). Fig. 133 D. (Synonyms: *Turbonilla decussata* Pease, 1861b, non A. Adams, 1861; *T. varicosa* A. Adams, 1853, non Forbes, 1844, Pilsbry, 1918.) Length, 19 mm; diameter, 5 mm. *Shell:* conic-elongate; slender; with fine, granular axial ribs and occasional varices, interspaces spirally striate; ivory to brown. *Spire:* protoconch a single large, heterostrophic whorl; teleoconch of about 12 convex whorls; suture impressed. *Sculpture:* fine, straight, convex axial ribs which are finely beaded; intercostal spaces spirally striate; with a thick varix on the alternate whorls. *Aperture:* subcircular; columella arcuate; outer lip with a varix. *Color:* variable — ivory, white, light brown.

This species is uncommon, found at depths of 8 to 100 m.

T. cornelliana is a variable species which is widely distributed in the Indo-West Pacific and is known by a variety of names, the best known perhaps that of *T. varicosa* A. Adams, 1855b. MacNeil (1960) records the species in Pliocene deposits in Okinawa.

Additional Records

Two species described or recorded from Hawaii have not been identified in recent collections: *Pyramidella canaliculata* Sowerby, 1873, described from the Hawaiian Islands, and *P. (Cossmannica) aciculata* A. Adams, 1854d, recorded by Dall and Bartsch (1906) from a specimen in the Paetel collection in Berlin. Three species attributable to Pilsbry are questionable: *O. pleurosigma* Pilsbry, 1918 is apparently a *nomen nudum; O. loxocephala* Pilsbry, 1918, may represent a juvenile of a well-known species; and *O. suta (= O. letsonae)* Pilsbry, 1918, is a rissoid.

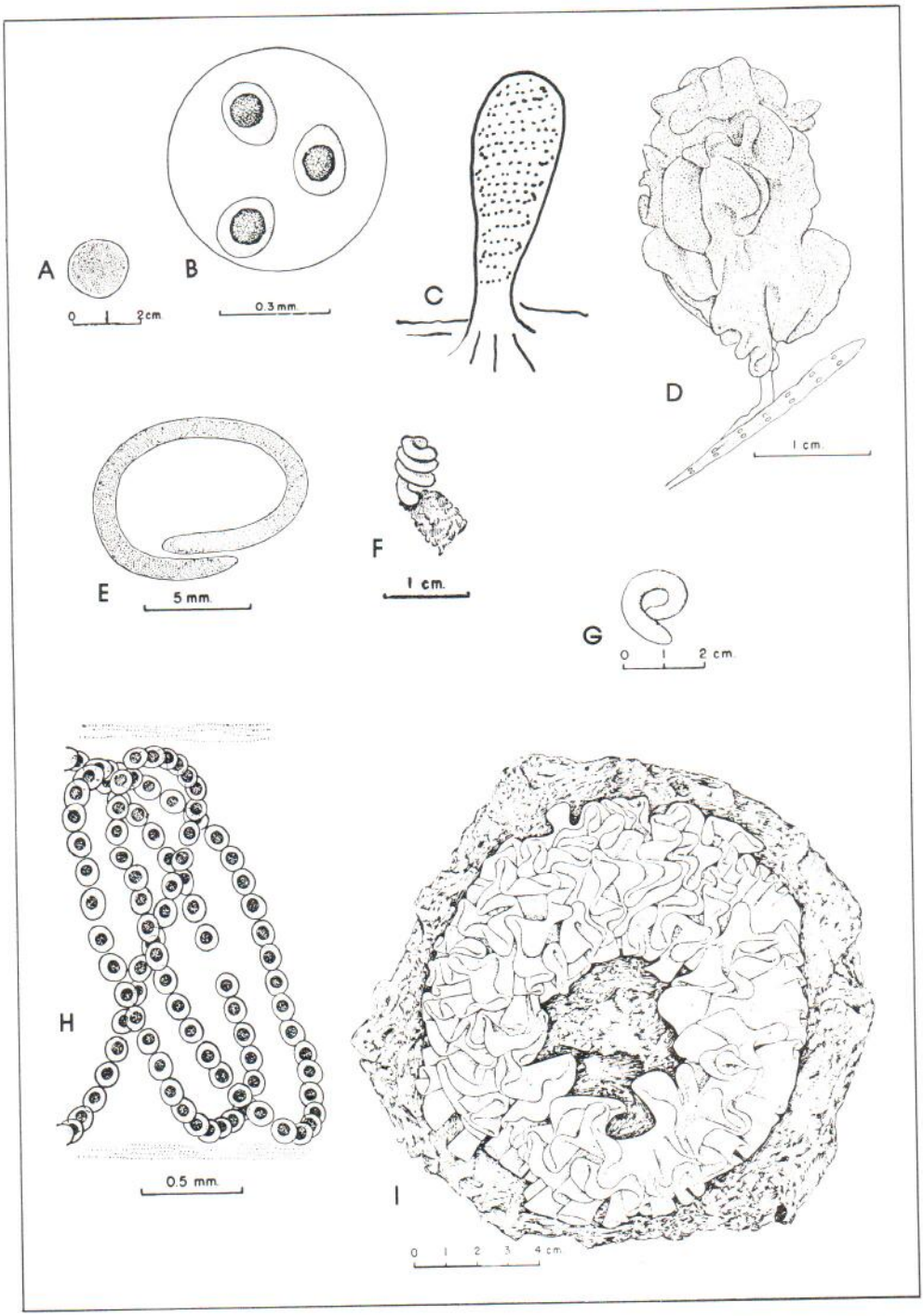


Figure 134.—Opisthobranch egg masses. A, B. Egg mass (A) and gelatinous capsule with ova (B) of *Atys semistriata*. C. Egg mass of *Philinopsis speciosa*. D. Egg mass of *Hydatina physis*. E, H. Egg mass (E) and magnified filament with ova (H) of *Bulla vernicosa*. F. Egg mass of *Bullina scabra*. G. Egg mass of *Haminoea crocata*. I. Egg mass of *Umbraculum sinicum*. (All except C from Ostergaard, 1950.)

Order CEPHALASPIDEA

The distinguishing feature of the Cephalaspidea, as their name implies, is a large head shield. The group is one of the largest among opisthobranchs, but may presently include forms which will eventually be better considered in other arrangements (see Rudman, 1972b). At present it includes most of the familiar shelled opisthobranchs, among them the "bubble shells," *Atys, Hydatina, Bulla,* and *Haminoea.*

Most cephalaspids are burrowers and several features of their anatomy are associated with this habit. Lateral upgrowths of the foot, the parapodia, invest the body with a smooth form; the eyes are sunk into the head shield; and the penis in most forms is invaginable.

Three superfamilies are included in the order: the Acteonacea with an exposed, spiral shell into which the animal can withdraw completely; and the Bullacea and Philinacea, in which the shell is reduced and there is increasing closure of the mantle over the shell.

Superfamily ACTEONACEA

This group of cephalaspids includes the most primitive members of the order, species of the genus *Acteon* in which the shell is spiral, well calcified, and an operculum is present. In other members of the group the shell is more open, less calcified, and there is no operculum. All members of the superfamily appear to feed on cirratulid and sabellid polychaetes (Hurst, 1965; Marcus and Marcus, 1967; Rudman, 1972b).

Family **Actaeonidae**

The actaeonids have well-developed pupiform or ovate shells capable of containing the entire animal. There is a small, horny operculum in some species. The shells are small to medium in size (11 to 12 mm in Hawaii), with a distinct spire, large last whorl, twisted columella, and sculpture of spiral grooves. The animals are white or colorless (Rudman, 1972a), the foot small and flattened, and the cephalic shield divided in front into lobes. *Acteon tornatalis* in Britain feeds on the tube worm *Owenia* (Hurst, 1965) and *Pupa kirki* in New Zealand on a sabellid worm (Rudman, 1972a).

The Hawaiian actaeonids are found in moderately deep to deep water. Elsewhere in the tropical Pacific, such as at Fanning Island (Kay and Switzer, 1974), actaeonids such as *Pupa* are common on sandy, intertidal lagoon reef flats.

Pupa pudica (A. Adams, 1854d). Fig. 135 B. Length, 11 mm; diameter, 6 mm. *Shell:* cylindrical; spirally corded with deep grooves; white. *Spire:* protoconch heterostrophic, of four whorls, white; teleoconch of three turreted, inflated whorls. *Sculpture:* prominent spiral cords, the interspaces of about equal diameter and finely scalloped. *Aperture:* narrow; outer lip thin, crenulate by the external sculpture; columella with a single massive fold. *Color:* white, occasionally with two spirals of black spots on the last whorl.

Shells have been recorded from depths of 40 m.

P. pudica was described from the Philippines.

Pupa tessellata (Reeve, 1842). Fig. 135 A. (Synonym: *Pupa thaanumi* Pilsbry, 1917.) Length, 12 mm; diameter, 5 mm. *Shell:* cylindrical-ovate, spire short, solid; with punctate spiral grooves; white maculated with flesh. *Spire:* protoconch heterostrophic, white, of three whorls, the apical tilting toward the apertural surface; teleoconch of eight inflated whorls. *Sculpture:* inequidistant spiral cords separated by punctate spiral striae. *Aperture:* narrow; outer lip thin; columella with a massive bifid fold and a single parietal fold. *Color:* ivory maculated with fleshy tones.

These mollusks are common, in sand, at depths of from 3 to 40 m. Beachworn shells are only occasionally encountered in drift.

P. tessellata was described from the Red Sea and is widely distributed in the Pacific.

Family **Bullinidae**

The members of this family are distinguished by large, well-calcified shells. The animals are operculate; there is an unpaired oral gland and esophageal crop, and the radular teeth have large denticulate hooks. Rudman (1972a) suggests they feed on polychaete worms.

Although *Bullina* has been included with the Aplustridae (= Hydatinidae), anatomical studies indicate that their anatomy is sufficiently different to justify their inclusion in a separate family (Rudman, 1972a).

Bullina scabra (Gmelin, 1791). Figs. 134 F; 135 E. (Synonyms: *Bullina lauta* Pease, 1860; *Bullina scabra solida* Pilsbry, 1921.) Length, 14 mm; diameter, 9 mm. *Shell:* ovate, inflated; spirally striate; white spirally banded and axially lineated with red. *Spire:* apex barely projecting; last whorl globose. *Sculpture:* close-set spiral cords separated by deep, punctate grooves. *Aperture:* large; outer lip simple, thin and sharp, extending from below the apex, flaring at the base; columella vertical, straight, with a slight fold above and obliquely truncate at the base. *Color:* white, with two red spiral lines dividing each whorl in three approximately equal parts, spirally banded with two thin red lines and with numerous arcuate axial red streaks. *Animal:* white.

These gastropods occur in shallow water in sandy tide pools, but are only occasionally encountered. The egg mass consists of a short, white cylindrical tube arranged in a spiral with one end attached to the substrate (Fig. 134 F) (Ostergaard, 1950).

B. scabra is a well known species in the Indo-West Pacific and has been recorded from Mauritius, the Sulu Sea, Australia, New Zealand, Japan, and various islands in the Pacific.

Bullina vitrea Pease, 1860. Fig. 135 C, D. Length, 11 mm; diameter, 7 mm. *Shell:* ovate; spirally grooved and punctured; white spirally banded with black threads. *Spire:* barely projecting; four whorls, the last large and convex. *Sculpture:* close spiral cords separated by deep striae with confluent, oblong punctures. *Aperture:* large, slightly contracted at the base where the outer lip flares; outer lip thin and sharp; columella straight, ending abruptly on the outer lip. *Color:* white, with two thin, black spiral threads, one below the suture on the last whorl, the other peripheral.

Shells are rarely encountered and only one or two living animals have been found in sandy pockets in meter-deep water along the shoreline.

B. vitrea is widely distributed in the Indo-West Pacific but is found under a variety of names in collections. *Bullina deshayesii* Pilsbry, 1894, from Reunion and *Perbullina errans* Iredale, 1929a, from New South Wales may be synonyms.

Family **Aplustridae**

(= **Hydatinidae**)

The globose shells of members of this family are large and inflated, only slightly calcified, and, for the most part, brightly colored. The columella is simply arcuate. The animals are large, the mantle and foot filmy and folded, and neither foot nor mantle can be contained completely within the shell. There is no operculum. *Hydatina* and *Micromelo* feed on polychaetes (Rudman, 1972b, 1972c).

Hydatina albocincta (van der Hoeven, 1839). Fig. 135 G. Length, 40 mm; diameter, 20 mm. *Shell:* globose, thin; smooth; cream with four or five wide brown spirals. *Spire:* sunken; last whorl expanded. *Sculpture:* microscopic growth striae only. *Aperture:* wide, outer lip extending from the shoulder; columella straight, flaring at the base. *Color:* cream with four or five wide spiral brown bands.

These hydatinids are rarely found, dredged from depths of 40 to 60 m.

This species may be restricted to the Pacific Ocean, found from Queensland westward. Iredale and McMichael (1962) consider *H. cinctoria* (Perry, 1811) an earlier name; Pilsbry (1893) distinguishes Perry's figure as representing an Indian Ocean species.

Hydatina amplustre (Linnaeus, 1758). Fig. 135 F. Length, 20 mm; diameter, 15 mm. *Shell:* globose; thin; smooth; pink spirally banded with white and black. *Spire:* short, projecting very slightly; last whorl expanded. *Sculpture:* microscopic growth striae only. *Aperture:* wide, the outer lip extending from a point below the shoulder; columella straight, flaring at the base. *Color:* pink, spirally banded with threads of black and wider bands of pink and with a thin, brown periostracum. *Animal:* white, with a large headshield divided into three pairs of lobes.

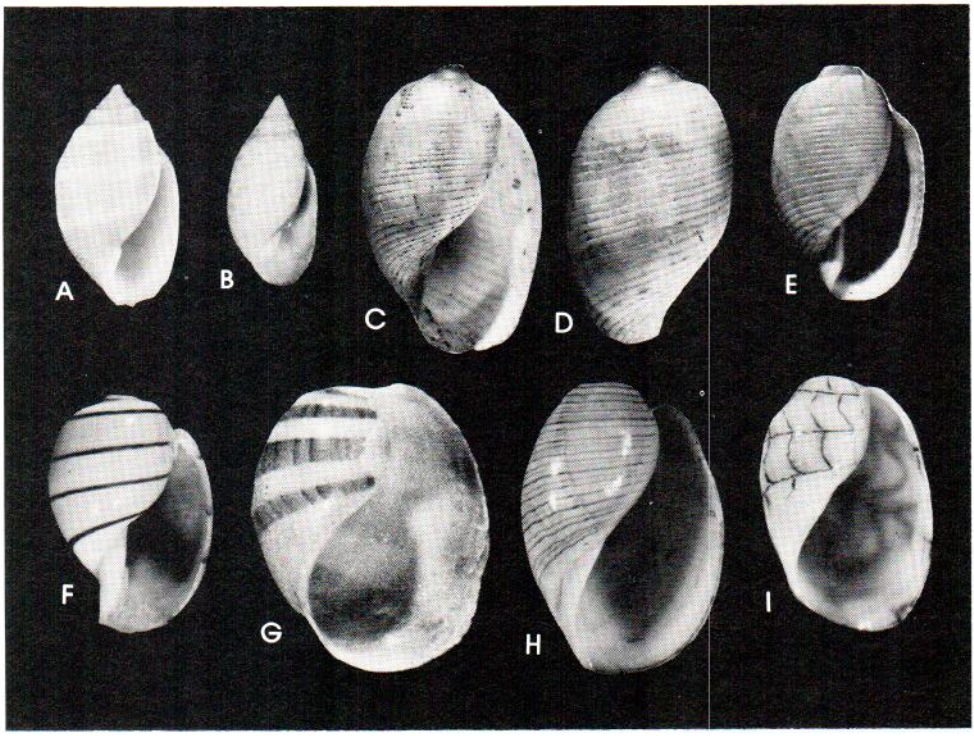


Figure 135.—Cephalaspid shells. A. *Pupa tessellata*, length 12 mm. B. *P. pudica*, length 11 mm. C, D. *Bullina vitrea*, length 11 mm. E. *B. scabra*, length 14 mm. F. *Hydatina amplustre*, length 20 mm. G. *H. albocincta*, length 40 mm. H. *H. physis*, length 26 mm. I. *Micromelo guamensis*, length 10 mm.

These opisthobranchs are common in shallow water, found in muddy, rubble-strewn areas along the shoreline where they burrow into the substrate. Cirratulid worms have been recovered from the crops of animals examined from Hawaii, suggesting that they feed specifically on polychaetes as does *H. physis* (Rudman, 1972b). Specimens are most often found from January through May when their spawn — elongate, fluted, white masses attached by a basal thread to the substrate — are noticeable.

H. amplustre is a familiar species throughout the Indo-West Pacific. Many authors refer this species to a separate genus or subgenus, *Aplustrum*, but Rudman (1972b) has shown that the anatomy of *H. amplustre* and *H. physis* is so similar that generic and subgeneric distinction is unnecessary.

Hydatina physis (Linnaeus, 1758). Figs. 131 A; 134 D; 135 H. Length, 26 mm; diameter, 19 mm. *Shell:* globose, thin; smooth; white spirally banded with black threads. *Spire:* sunken; suture channeled; last whorl inflated. *Sculpture:* smooth, with growth striae only. *Aperture:* wide; the outer lip simple, thin, extending from a point below the apex of the spire, and flaring at the base; columella simply arcuate. *Color:* spirally banded with numerous black threads; periostracum thin, buff-colored. *Animal:* fawn-pink with an iridescent blue border around the head shield and edges of the foot.

Like *H. amplustre*, this species is most commonly seen from January to May when the egg masses, white curly skeins attached to the substrate, are noticeable; the egg masses are distinguished from those of *H. amplustre* by their longer outline and less convolute habit. These hydatids feed exclusively on cirratulid polychaetes (Rudman, 1972b). Some animals grow to enormous size: shells 44 mm long and 31 mm in diameter were collected at Pearl and Hermes Reef by the *Tanager* Expedition in 1923.

This species is found throughout the Indo-West Pacific from South Africa to New Zealand and Japan, and in the Caribbean and Canary Islands. The eastern American shells are sometimes distinguished as *H. vesicaria* (Lightfoot, 1786) (Abbott, 1974).

Micromelo guamensis (Quoy and Gaimard, 1825). Fig. 135 I. (Synonym: *Bulla scripta* Garrett, 1857.) Length, 10 mm; diameter, 8 mm. *Shell:* ovate; smooth; white with spiral and axial black lines. *Spire:* rather flat at the apex, last whorl short. *Sculpture:* microscopic growth striae only. *Aperture:* wide at the base, narrow apically; outer lip simple — extending from the apex; columella arcuate. *Color:* white, with three spiral black threads and two or three wavy, axial black threads. *Animal:* transparent pale yellow, spotted with opaque white and with a yellow margin around the foot and headshield.

Specimens of *M. guamensis* are common in shallow water, usually found crawling on algae in tide pools and shoreward on fringing reefs.

This species was described from Guam and is widespread in the Indo-West Pacific from Japan in the north to New South Wales, Australia, in the south.

Superfamily BULLACEA

These cephalaspids are characterized by their herbivorous habit, and they have a broad radular ribbon with many rows of hook-shaped teeth and a grinding gizzard. The group includes forms with globose, lightly calcified shells (Bullidae and Atyidae), and soft-bodied, almost bilaterally symmetrical animals with reduced shells (Smaragdinellidae).

Family **Smaragdinellidae**

The smaragdinellids are herbivorous gastropods in which the parapodia partially or completely envelope the shell which is rudimentary and small, without obvious traces of coiling externally. Like *Haminoea* and *Atys*, they have a broad radular ribbon with many rows of hook-shaped teeth and a grinding gizzard with three large, ridged, chitinous plates (Rudman, 1972e). Two genera are found in Hawaii, *Smaragdinella* with a partially exposed shell, and *Phanerophthalmus* in which the shell is almost completely hidden.

Phanerophthalmus cylindricus (Pease, 1861c). Fig. 136 B. Length, 12 mm; diameter, 4 mm. *Animal:* elongate, cylindrical; sides nearly parallel, slightly broader

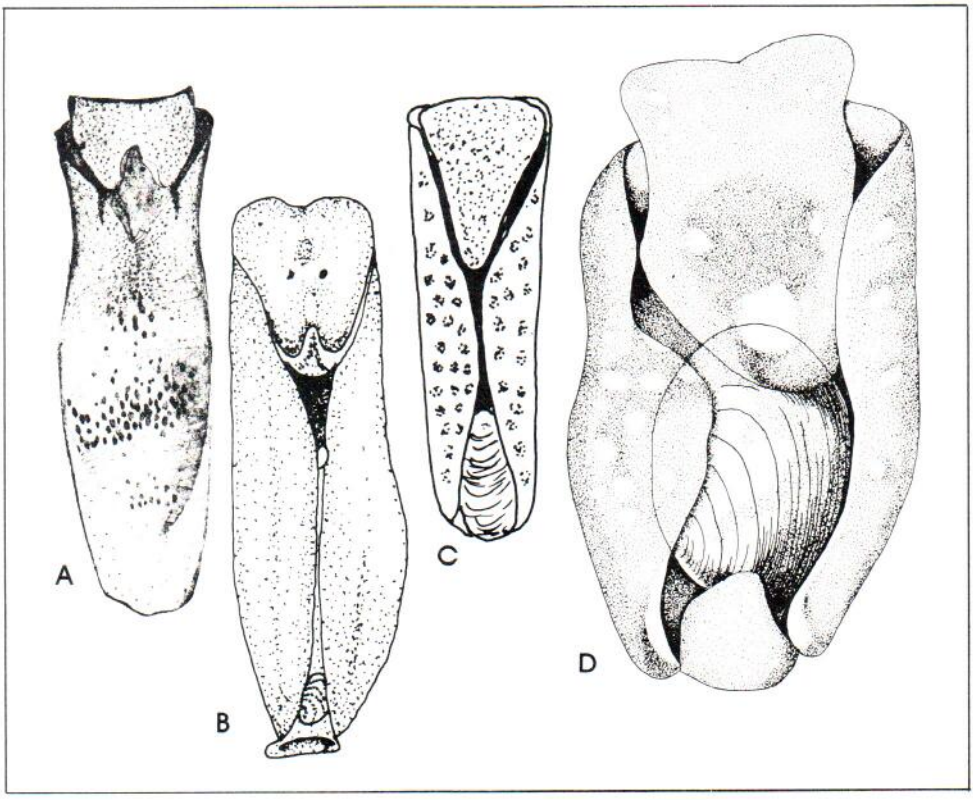


Figure 136.—A. *Atys semistriata*, shell length 13 mm. B. *Phanerophthalmus cylindricus*, length 12 mm. C. *P. smaragdinus*, length 12 mm. D. *Smaragdinella calyculata*, length 14 mm.

anteriorly than posteriorly; cephalic shield short, about one-third the length of the body, obtusely rounded posteriorly; parapodia enveloping the body, extending from the head posteriorly. *Shell:* light and thin, barely visible posteriorly in the animal. *Color:* animal dusky, the margins of the cephalic shield paler than the central portion which is densely freckled with black and white and with a few rusty-red spots; foot transparent white. Shell white.

These opisthobranchs are found well hidden among the stipes of the green alga *Vallonia*, and, because of their small size and cryptic color, are only occasionally found.

The Hawaiian animals are quite comparable with Pease's description of *Cryptophthalmus cylindricus* from Tahiti, and the habitat in algae is similar to that reported by Eliot (1900) for the species in Samoa.

Phanerophthalmus smaragdinus (Ruppell and Leuckart, 1831). Fig. 136 C. Length, 12 mm. *Animal:* elongate, cylindrical, narrow in front, slightly swollen behind; head shield small, narrowing posteriorly to a pair of small lobes; foot with parapodia folding up and over the animal, overlapping one another; shell partially

enclosed, lying dorsally within the mantle shield and projecting from the posterior end of the body; right side of mantle shield extending in a clockwise direction, forming a funnel. *Color:* white speckled with brown and opaque white. Pilsbry (1895-96) described the animals as emerald green mingled with light green; Baba (1936) described them as yellow green.

These opisthobranchs are rare, dredged from depths of 50 m.

P. smaragdinus was described from the Red Sea and occurs through the Indo-West Pacific to southern Japan and Fiji.

Smaragdinella calyculata (Broderip and Sowerby, 1829). Fig. 136 D. (Synonym: *Smaragdinella viridis* (Rang), Martens and Langkavel, 1871.) Length, 14 mm; diameter, 8 mm. *Animal:* cephalic shield extending to the middle of the body; lateral parapodial lobes and a posterior lobe curling over the shell. *Shell:* caplike, solid; apex concealed, the columellar border forming a cup-shaped process projecting into the aperture; outer lip angular, thin. *Color:* shell yellow in living animals, callus-white externally and dark green internally in beachworn specimens. *Animal:* dark green, mottled and freckled with white.

These cephalaspids are abundant, found limpetlike fairly high along the shoreline on bare rock, sometimes in areas left dry by the receding tide. They produce abundant mucus and are often closely attached to the substratum. The egg masses are cylindrical, yellow, and gelatinous.

S. calyculata is distributed throughout the Indo-West Pacific; in the Pacific it occurs in central and southern Japan and Okinawa, the Marianas and Marshall Islands, Pitcairn and Easter Island (Marcus and Burch, 1965), and the Solomon Islands (Rudman, 1972e).

Family **Bullidae**

The shell in *Bulla* is distinguished by its involute apex and sunken spire; it is globose, smooth, and usually has a mottled color pattern. The animals have a large head shield which is truncated anteriorly and bilobed posteriorly; there are neither parapodial nor epipodial lobes.

Bulla vernicosa Gould, 1859. Figs. 134 E, H; 137 E. (Synonyms: *Bulla marmorea* Pease, 1861b, non *marmorea* Schröter, 1804; *B. peasiana* Pilsbry, 1893.) Length, 25 mm; diameter, 15 mm. *Shell:* oval, globose; smooth and polished; brown mottled with darker and lighter. *Spire:* sunken; last whorl globose. *Sculpture:* microscopic growth striae only. *Aperture:* narrow apically, flaring basally; columella smooth, arcuate. *Color:* brown, mottled variously with darker and lighter brown and cream. *Animal:* exposed parts yellow or orange, flecked with white.

These opisthobranchs are abundant between January and April every two or three years, and only occasional animals are seen during the same months of the intervening years. They emerge by the thousands in silty, rubble-strewn and sandy areas along the shoreline, spawn, and then the populations die off within six to eight weeks and their shells are washed ashore. More than one thousand shells were collected along the

wave line of shores on Kauai and Oahu between January and April of 1965, but the same areas yielded fewer than 10 shells each during the same months in 1966 and 1967.

These mollusks are herbivorous, apparently feeding on the green alga *Enteromorpha*. The egg mass is aplysioidlike consisting of tangled skeins of yellow threads, each thread containing a linear series of single egg capsules. As in *Hydatina physis*, some animals grow to enormous size with shells up to 47 mm in length.

B. vernicosa is widespread in the Pacific ranging as far south as northern New Zealand.

Family **Atyidae**

The shells of the atyids are thin, inflated, and involute, with a long aperture, and with the outer lip projecting beyond the aperture and base. Most shells are white or yellow. The surface is smooth or finely striated. There are three genera in Hawaii: *Atys* with a short, truncate columella and outer lip which projects sharply at the apex and base; *Diniatys* with a prominently toothed columella; and *Haminoea* with a gently curving outer lip.

The animals resemble those of the Bullidae, but they are able to withdraw completely into the shell. Atyids live in sandy, silty substrates. When the animal is moving, it encloses itself in a mucous tube produced by glands of the foot and head shield; the mucous sheet collects and holds particles of sand and silt and the animal thus moves through a continuously produced mucous tube without becoming clogged with mud or detritus (Rudman, 1971). In *Haminoea* and *Atys* the head shield is large, the anterior edges forming temporary funnels which direct water through the mantle cavity (Rudman, 1971). The posterior end is usually divided into a pair of short, posterior lobes, and lateral lobes of the foot are folded over the shell.

Atys debilis Pease, 1860. Fig. 137 C. (Synonym: *Atys cornuta* Pilsbry, 1917.) Length, 13 mm; diameter, 6 mm. *Shell:* cylindrical, thin; outer lip ascending beyond the apex where it forms a sinus; spirally grooved apically and abapically; white. *Spire:* sunken, twisting below the outer lip; apex narrower than the body of the last whorl which is cylindrical and slightly inflated. *Sculpture:* smooth except for approximately 14 spiral grooves at the apex and 10 near the base and occasional axial growth striae. *Aperture:* narrow; outer lip thin and ascending above the apex, terminating in a sharp projection and narrow sinus, flaring and truncate at the base; columella almost straight. *Color:* white.

Shells of *A. debilis* are found at depths of more than 20 m.

The Hawaiian shells superficially resemble those of a well-known Indo-West Pacific species, *A. cylindrica* Helbling, 1779, but the shells of the latter are larger and thicker than those of *A. debilis*, and they are also distinguished by the wider apex, apical sinus, more ovate last whorl, and gray periostracum.

Although *A debilis* is recorded from Fiji (Watson, 1886), the Fijian shells may represent juveniles of *A. cylindrica* and for the present *A. debilis* is considered as occurring only in the Hawaiian Islands.

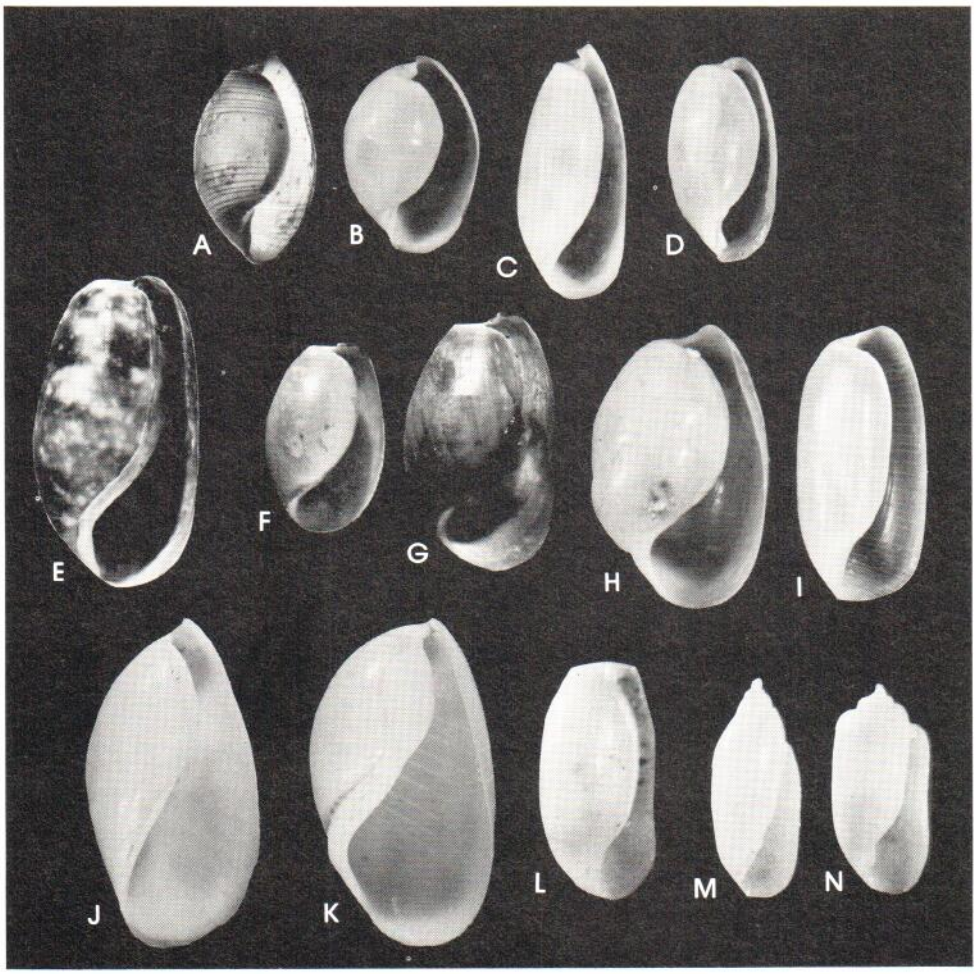


Figure 137.—A. *Atys semistriata*, length 13 mm. B. *A. kuhnsi*, length 16 mm. C. *A. debilis*, length 13 mm. D. *Diniatys dentifer*, length 10 mm. E. *Bulla vernicosa*, length 18 mm. F. *Haminoea crocata*, length 7 mm. G. *H. galba*, length 17 mm. H. *H. cymbalum*, length 18 mm. I. *H. curta*, length 7 mm. J. *Scaphander alatus*, length 30 mm. K. *S. pustulosus*, length 33 mm. L. *Cylichna pusilla*, length 4 mm. M. *Acteocina hawaiensis*, length 2.5 mm. N. *A. sandwicensis*, length 3 mm.

Atys kuhnsi Pilsbry, 1917. Fig. 137 B. (Synonym: *Atys naucum* (Linnaeus, 1758), Cernohorsky, 1972a, in part.) Length, 16 mm; diameter, 10 mm. *Shell:* globose; spirally striated; semitransparent; white or with narrow axial streaks of brown. *Spire:* sunken; apex sloping abapically with a small, shallow concavity about the axis; last whorl widest above the middle. *Sculpture:* polished; with spiral striae; in small specimens the striae are continuous over the last whorl, in large specimens they are obsolete or absent in the center. *Aperture:* rather wide; outer lip extending above the apex with a fold at the apex; columella narrow, nearly straight, with a slight prominence medially; narrowly umbilicate. *Color:* transparent, white, opaque at the apex and base; occasionally with narrow axial streaks of dark or cinnamon-brown.

Shells have been dredged at depths of 20 to 40 m, but nothing is known of the habits of the living animal.

A. kuhnsi was described from the Hawaiian Islands. Although Cernohorsky (1972a) considers shells of *A. kuhnsi* as representing juveniles of the widespread Indo-West Pacific *A. naucum* (Linnaeus, 1758), the Hawaiian shells are consistently distinguished from those occurring elsewhere by their smaller size, thin, fragile texture and deep-water habit.

Atys semistriata Pease, 1860. Figs. 134 A, B; 136 A; 137 A. (Synonyms: *Atys semistriata mua* Pilsbry, 1921; *A. semistriata fordinsulae* Pilsbry, 1921.) Length, 13 mm; diameter, 6 mm. *Shell:* globose, thin and fragile; with spiral striae apically and at the base; transparent white. *Spire:* sunken; last whorl narrow and angular at the apex, sloping abapically and separate from the outer lip. *Aperture:* narrow apically, wider at the base where the columella is arcuate; outer lip ascending above the apex, straight-edged, channeled at the base. *Sculpture:* six to eight spiral striae apically and on the base, the intervening area smooth. *Color:* white. *Animal:* transparent white, peppered with black on head shield and mantle; dorsum with three bands of red; parapodial lobes barely extending over the sides of the shell. The animals are very active; and when they are moving, the anterior lobes of the head shield stand upright.

These gastropods are common in shallow water, especially in shallow sandy areas as in Kaneohe Bay, Oahu. Ingram (1939c) suggests they feed on the bryozoan *Bugula neritina* with which the mollusks are often associated. The egg masses consist of transparent gelatinous balls approximately 15 mm in diameter; in the older egg masses the eggs are pink.

The shells of *A. semistriata* superficially resemble the widespread Indo-West Pacific species, *A. naucum* (Linnaeus, 1758), but Hawaiian shells are smaller (*A. naucum* often reaches more than 40 mm in length), and are delicate and transparent. Juvenile specimens of *A. naucum* appear to be indistinguishable from the Hawaiian shells and no attempt is made here to indicate a distribution for *A. semistriata* other than its occurrence in the Hawaiian Islands.

Diniatys dentifer (A. Adams, 1850b). Fig. 137 D. (Synonym: *Dinia compitorum* Pilsbry, 1921.) Length, 7 mm; diameter, 4 mm. *Shell:* cylindrical; spire sunken; outer lip rising above apex; smooth and fragile; columella projecting toothlike at the base; white. *Spire:* sunken, apex angular and sloping abapically; outer lip rising from the apex; last whorl inflated. *Sculpture:* smooth or with obsolete spiral striae becoming more distinct at the base. *Aperture:* narrow; wider at the base where the columella is deeply arcuate; outer lip extending above the apex; thickened within; columella projecting toward the outer lip in a toothlike projection at the base. *Color:* white.

Shells of *D. dentifer* are only occasionally found in beach drift among the windward islands, but were abundant on the beaches at Midway in March, 1971.

This species is well known in the Indo-West Pacific; Habe (1952) records it from Okinawa.

Haminoea crocata Pease, 1860. Figs. 134 G; 137 F. Length, 7 mm; diameter, 5 mm. *Shell:* ovate; pale yellow. *Spire:* involute; apex shouldered. *Sculpture:* with

occasional microscopic axial striae only. *Aperture:* narrow; the outer lip rising at the apex, flaring basally but incurved apically; columella concave, the base reflected. *Color:* pale yellow or straw-colored. *Animal:* pale green, freckled and spotted with darker green, black, and rust; a spot of crimson between the eyes.

This is the most abundantly occurring species of *Haminoea*, and the animals are commonly found throughout the year buried in sand on algal mats on rocks in shallow waters inshore of fringing reefs, in tide pools, and on benches. These mollusks are the most common food species of the molluscivorous cone, *Conus pennaceus* (Kohn, 1959a).

H. crocata was described from the Hawaiian Islands; it has also been recorded from New South Wales (Kobelt, 1896); the Torres Straits (Melvill and Standen, 1899), and Karachi (Melvill and Standen, 1901); shells from New Caledonia are also comparable to the Hawaiian shells.

Haminoea curta (A. Adams, 1850b). Fig. 137 I. (Synonyms: *Haminoea curta tomaculum* Pilsbry, 1917; *H. tomaculum* Pilsbry, 1921; *H. olopana* Pilsbry, 1921.) Length, 7 mm; diameter, 3.5 mm. *Shell:* cylindrical-ovate; with spiral striae; white. *Spire:* apex involute; of one and one-half whorls. *Sculpture:* microscopically spirally striate with fine, rather evenly spaced striae. *Aperture:* outer lip rising above the apex, blunt; abapical end also blunt; columella slightly curved; narrowly umbilicate. *Color:* white.

These animals are common at depths of 12 to 25 m, and shells are occasionally found in beach drift.

H. curta also occurs in the Ryukyu and Amami Islands.

Haminoea cymbalum (Quoy and Gaimard, 1835). Fig. 137 H. (Synonyms: *Haminoea simillima* Pease, 1868c; *H. aperta oahuensis* Pilsbry, 1921; *H. crocata* Pease, Ostergaard, 1950.) Length, 18 mm; diameter, 10 mm. *Shell:* ovate-globose; white. *Spire:* involute, of one and one-half whorls, the last whorl globose. *Sculpture:* smooth, with occasional growth lines. *Aperture:* narrow; outer lip slightly produced posteriorly. *Color:* white. *Animal:* pale green distinctively marked with maplike orange and blue lines.

This is a common shallow water species; the animals are abundant in rocky areas shoreward on fringing reefs, in tide pools, and on solution benches from August through December.

H. cymbalum appears to be widely distributed throughout the Indo-West Pacific: it was described from Tahiti; Rudman (1971) records it from Fiji; I have seen it in Samoa and the Mariana Islands; and Martens (1880) figures it (unnamed) from Mauritius.

Haminoea galba Pease, 1861b. Fig. 137 G. (Synonym: *Haminea sandwichensis* Sowerby, 1868.) Length, 17 mm; diameter, 10 mm. *Shell:* ovate; yellow with brown spiral striae. *Spire:* involute, apex shouldered; last whorl inflated. *Sculpture:* finely spirally striate and with occasional axial growth lines. *Aperture:* outer lip nearly straight, slightly protruded posteriorly; inner lip somewhat thickened at the base;

columella curved but not protruding beyond the base. *Color:* yellow, spiral striae brown.

These animals are not often seen but there are a number of shells representing the species in various collections in the Islands.

This species was described from the Hawaiian Islands.

Additional Records

Atys costulosa Pease, 1869b, described from the Hawaiian Islands, is distinguished by axial ribs and spiral striae at both ends; Pilsbry (1921) recognized fossil shells from Waimalu, Oahu, but specimens of living animals have not been identified since Pease's description. *A. kekele* Pilsbry, 1921, was described from fossil shells collected near Waipahu, Oahu; the shells are distinguished from those of *A. cylindricus* (Helbling, 1779) by the narrower aperture, deeper apical excavations, and more effuse base. *Haminoea adamsii* Dunker, 1862, may be an older name for *H. galba* Pease, but the description is so brief as to make positive identification difficult. A single specimen of an animal which may represent *H. ovalis* Pease, 1868c, described from Tahiti, is known from Coconut Island, Kaneohe Bay, Oahu; the animal as Pease described it is "pale watery green dotted with orange and purple."

Superfamily PHILINACEA

The three families included in this group of cephalaspids encompass a range of forms: the Scaphandridae have well-developed shells, the Philinidae and Aglajidae have reduced shells enclosed by the mantle, or no shell at all. The animals are carnivorous, feeding on foraminiferans, worms, and mollusks.

In Hawaii, the family Philinidae is represented by at least one species recorded from depths of several hundred meters, the Scaphandridae by shells found at depths of from 10 to 600 m, and the Aglajidae by five species that are common in shallow, intertidal waters.

Family **Aglajidae**

These cephalaspids are soft-bodied, ovate or elongate, and the shell is thin and small, almost entirely enclosed. In *Philinopsis* the head shield is truncate with a median crest, the parapodia partially enclose the notum and the posterior shield often terminates in a fanlike tail. The shell is large and flat, the edge strongly calcified, but the rest is thin. In *Chelidonura* the body is narrow, the head shield triangular with the posterior end tapering to a point; the parapodia are large, folding over and enclosing the notum, with the posterior lobes long and tapering, the left usually longer than the right. The shell is flattened and internal, but fairly strongly calcified. The aglajids are canivorous, feeding on other mollusks *(Philinopsis speciosa)* or worms *(P. pilsbryi)* (Rudman, 1972d).

Chelidonura amoena Bergh, 1905. Fig. 138 G. Length, 8 mm; diameter, 2 mm. *Animal:* elongate, slender; cephalic shield truncate, mantle shield bifurcate posteriorly,

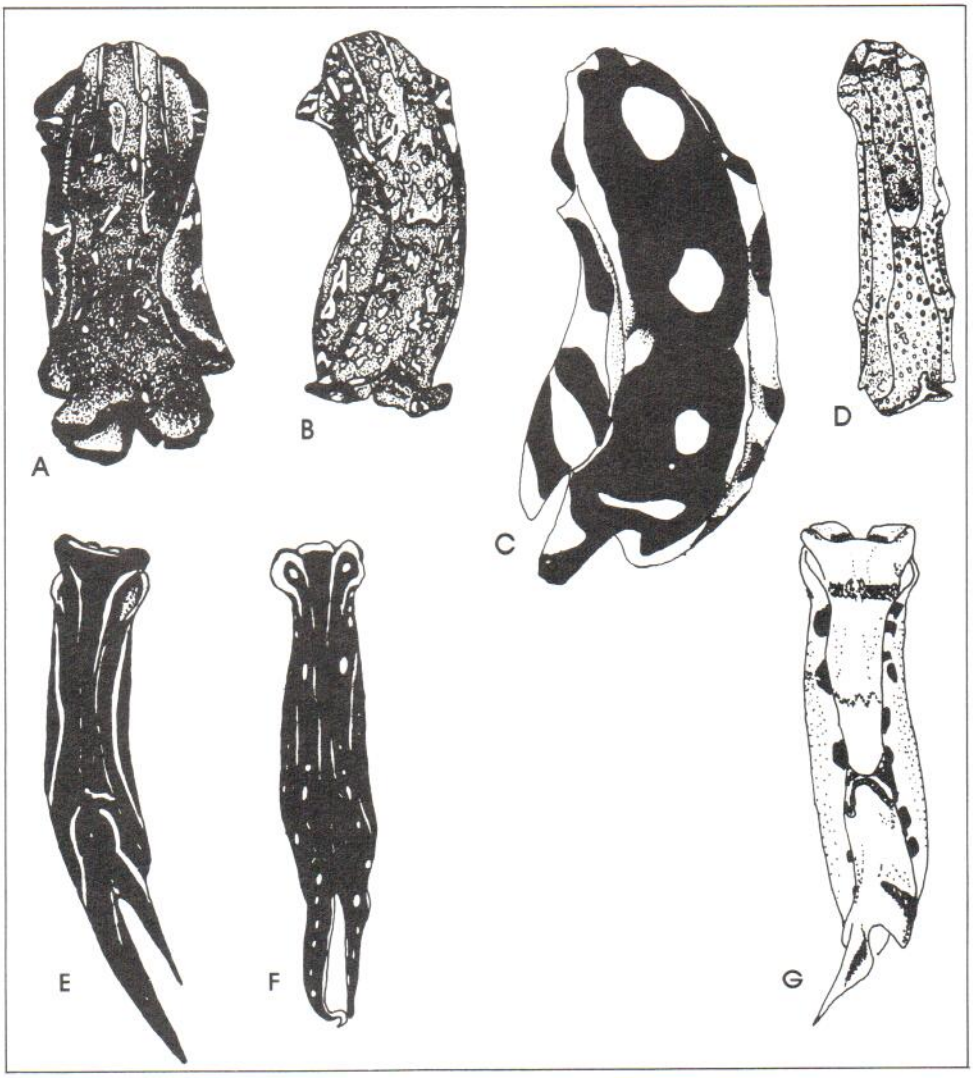


Figure 138.—**Aglajidae.** A, B. *Philinopsis speciosa*, length 50 mm, two color forms. C. *P. pilsbryi*, length 50 mm. D. *P. orientalis*, length 23 mm. E, F. *Chelidonura hirundinina*, length 20 mm, two color forms. G. *C. amoena*, length 8 mm. (All by R. Kawamoto.)

the left lobe a long, slender "tail," the right shorter. *Color:* cream with splashes of opaque white and black freckling; the bifurcate parapodia also splashed with yellow.

These cephalaspids are found among the stipes of the algae *Boodlea* and *Jania* where they are well hidden.

C. amoena was described from the Sula Sea.

Chelidonura hirundinina (Quoy and Gaimard, 1833). Fig. 138 E, F. (Synonym: *Chelidonura hirundinina* var. *elegans* Bergh, 1900.) Length, 20 mm; diameter, 4

mm. *Animal:* elongate, slender; cephalic shield truncate, mantle shield bifurcate posteriorly, the left lobe a long, slender "tail," the right somewhat shorter. *Color:* velvet black, the cephalic shield with a transverse orange bar and margined with blue and yellow, mantle and epipodia margined with blue and yellow.

These mollusks are among the most spectacularly colored of the cephalaspids. They are found in shallow water on the algae *Spyridia* and *Padina*, and are most common in July and August.

C. hirundinina is a well-known species in the Indo-West Pacific; it was described from Mauritius, and in the Pacific has been recorded from New South Wales (Angas, 1864), Sagami Bay and Kii, Japan (Baba, 1949). Bergh (1900) described the variety *elegans* from Laysan and Marcus and Burch (1965) report it as a subspecies in the Marshall Islands.

Philinopsis orientalis (Baba, 1949). Fig. 138 D. Length, 23 mm; diameter, 7 mm. *Animal:* cylindrical, elongate, slender; cephalic shield bluntly rounded anteriorly; posterior lobes of the mantle fanlike and equal in size. *Color:* dark brown minutely spotted with white; cephalic shield banded anteriorly and posteriorly with white and yellow and two similar bands on the epipodia; posterior "fans" edged with white and yellow; foot lighter than the dorsum.

These opisthobranchs are uncommon, found in shallow water shoreward of fringing reefs. The egg mass is club-shaped and gelatinous.

P. orientalis was described from Sagami Bay, Japan.

Philinopsis pilsbryi (Eliot, 1900). Fig. 138 C. (Synonyms: *Philinopsis nigra* Pease, 1860; *Aglaja pilsbryi hawaiensis* Pilsbry, 1921.) Length, 50 mm; diameter, 35 mm. *Animal:* elongate-oval. Head shield elongate-triangular, one-quarter the body length; posterior corners of head shield rounded, posterior edge in midline forming a pointed crest which is raised when the animal is moving. Posterior shield rounded anteriorly and extending back beyond the edge of the foot where small flaps fold down partially enclosing the posterior end of the mantle cavity. Parapodia large, folding up and covering the sides of the head shield and posterior shield. Mouth bordered by a pair of large mounds bearing long, retractile sensory bristles. *Color:* white with a brown-black pattern, the dark color sometimes forming "figures of eight," the ventral surface usually with little black patterning.

These cephalaspids are common from June to August in localized sandy areas, such as Kaneohe Bay, Oahu.

P. pilsbryi is widespread through the Indo-West Pacific, from the Red Sea to Samoa and Fiji. Although *P. nigra* Pease was described from the Hawaiian Islands and the name has priority over Eliot's name, Rudman (1972d) considers it a *nomen oblitum* because it had not been used for more than 50 years.

Philinopsis speciosa Pease, 1860. Figs. 134 C; 138 A, B. Length, 60 mm; diameter, 25 mm. *Animal:* elongate-oval; head shield oblong-triangular, half the body length, posterior corners rounded; posterior edge in midline forming a pointed crest which is raised when the animal is moving; posterior shield rounded anteriorly and

extending back beyond the edge of the foot where small flaps fold down partially enclosing the posterior end of the mantle cavity. Parapodia large, folding up and covering the sides of the head shield and posterior shield. Mouth bordered by a pair of large mounds bearing long, retractile sensory bristles. *Color:* ground color light to dark brown, spotted and speckled with white, a pair of light orange-brown parallel lines on the head shield; margin of parapodia variegated black and yellow. Foot lighter than dorsum, with a purple tint and margined with the colors of the dorsum.

These animals are common in localized sandy areas, such as at Pupukea, Oahu, from June to August. The egg masses are club-shaped, transparent gelatinous masses, 75 mm in length, 25 mm in diameter. They are attached by a narrow stalk beneath the surface of the sand; the eggs are in chains which wind through the gelatinous substrate. (Fig. 134 C.)

This species appears to be endemic to the Hawaiian Islands (Rudman, 1972d).

Additional Records

Aglaja nuttalli Pilsbry, 1895, was described from a preserved specimen 40 mm in length, 22 mm in diameter; it is black-brown, the sole of the foot of the same color but with faintly discernible lighter maculations. The description is insufficient to provide further determination of the species.

Family **Scaphandridae**

In this family the shell is variously developed, elongate or ovate, smooth, and with an involute or projecting apex. The parapodia are large and thick and there is a short cephalic shield which is truncate posteriorly. These mollusks are carnivorous: in British waters members of the genus *Scaphander* feed on other mollusks (Fretter, 1939).

Acteocina hawaiensis Pilsbry, 1921. Fig. 137 M. Length, 2.35 mm; diameter, 1 mm (type dimensions). *Shell:* cylindrical; spire projecting; with coarse wrinkles; white with gray spots. *Spire:* protoconch heterostrophic; teleoconch of three whorls, the last cylindric and shouldered below the deep suture. *Sculpture:* coarse axial growth striae. *Aperture:* narrow, outer lip thin, barely flaring at the base; columella straight apically and arcuate abapically. *Color:* white with five or six spirals of gray spots.

These animals apparently occur in deep water; shells are known only from worn specimens dredged at depths of 6 to 25 m off Lahaina, Maui.

A. hawaiensis was described from the Hawaiian Islands.

Acteocina sandwicensis Pease, 1860. Fig. 137 N. (Synonym: *Acteocina honoluluensis* Pilsbry, 1917.) Length, 3 mm; diameter, 2 mm. *Shell:* cylindrical with a sharply pointed spire; smooth; white. *Spire:* protoconch heterostrophic, of two white whorls; teleoconch of four whorls, suture impressed. *Sculpture:* microscopic growth striae only. *Aperture:* narrow; outer lip thin, barely flaring at the base; columella with a single median fold. *Color:* white.

Although shells are commonly found in beach drift and occasionally in tide pools, these opisthobranchs are more common at depths of from 3 to 18 m.

Pilsbry (1917) distinguishes *A. honoluluensis* from Pease's *A. sandwicensis* on the basis of the projecting spire in the former species and a partially immersed protoconch in the latter, but a distinction between two species does not appear necessary because the protoconch is a notoriously variable feature in tectibranchs.

A. sandwicensis is recorded from the Tuamotus by Dautzenberg and Bouge (1933), and shells comparable with the Hawaiian shells have been seen from Suez (as *Tornatina olivaeformis* Issel, 1869), the Loyalty Islands (as *Tornatina hadfieldii* Melvill and Standen, 1896), and Fanning Island, Line Islands (Kay, 1971).

Cylichna pusilla (Pease, 1860). Fig. 137 L. Length, 3.5 mm; diameter, 2 mm. *Shell:* cylindrical, solid; apex involute; with spiral striae; white. *Spire:* one and one-half whorls, the last whorl not separate from the lip, apex truncate. *Sculpture:* minute punctate spiral striae. *Aperture:* narrow; outer lip thickened, barely rising above the apex to which it is attached by a shallow sinus, narrow and V-like at the base; columellar straight. *Color:* white.

This species is known only from shells found in beach drift, and at depths of 10 to 50 m.

C. pusilla was described from the Hawaiian Islands.

Scaphander alatus Dall, 1895. Fig. 137 J. Length, 35 mm; diameter, 20 mm. *Shell:* oval, broadly cylindrical; outer lip rising sharply above the apex; polished; white. *Spire:* apex barely sunken; last whorl globose. *Sculpture:* faint growth lines crossed by spiral punctate striae becoming grooves basally. *Aperture:* narrow apically, wider abapically; outer lip sharp; columella arcuate and reflected. *Color:* white, with a thin wash of callus; periostracum pale straw-colored.

This is a deep-water species; shells were dredged by the *Albatross* at a depth of 596 m.

S. alatus was described from the Hawaiian Islands.

Scaphander pustulosus Dall, 1895. Fig. 137 K. Length, 33 mm; diameter, 20 mm (type dimensions). *Shell:* ovate; outer lip rising above the apex, aperture broad; with deep, punctate striae; cream-white. *Spire:* apex barely immersed; last whorl globose, short. *Sculpture:* with spirals of punctate striae, the punctures overlapping one another and separating wide, flat cords of unequal diameter. *Aperture:* narrower apically, flaring abapically; outer lip thin, rising above the apex; inner lip thick, callous; columella arcuate, pustular. *Color:* cream-white, with a thin creamy periostracum.

Like *S. alatus,* this species is a deep-water form and the only specimens recorded are those dredged by the *Albatross* at a depth of 590 m and by the *Pele* at a depth of 80 m.

S. pustulosus was described from the Hawaiian Islands.

Orders THECOSOMATA and GYMNOSOMATA

(PTEROPODA)

These pelagic mollusks were formerly grouped together in the Pteropoda, sometimes called the "sea butterflies" because of the foot which is expanded as muscular "wings" functioning in moving the animals through the water. Two orders are now recognized, the carnivorous Gymnosomata without shells which occupy surface waters by day, and the nocturnal ciliary feeding Thecosomata with shells. The shells of the thecosomes are fragile and glassy, and may accumulate in enormous numbers in sediments on the ocean floor where they constitute what is called "pteropod ooze."

Although seldom found in beach drift, these mollusks comprise a conspicuous element of the pelagic fauna in waters around the Hawaiian Islands. A dozen species were recorded in net and dredge hauls from the *Challenger* (Pelseneer, 1888), ten species in dredge hauls of the *Albatross,* six in the collections of the *Dana* (Tesch, 1949), and 21 are recorded from subtropical water (between 25° and 35° N) in investigations of tuna fishing grounds (Hida, 1957). Shells representing genera from one family of the Thecosomata are illustrated.

Family **Cavolinidae**

In this family the shell takes various shapes: needlelike, flattened, triangular, inflated, and bilaterally symmetrical with a median axis. There is no operculum. Representatives of five genera are illustrated:

Cavolinia (Fig. 139 E, F). Dorsoventrally inflated, aperture with hoodlike projections; with elongate spines; white to brown.

Clio (Fig. 139 A, B). Dorsoventrally compressed, angular, with lateral keels and a midrib on the dorsum; colorless.

Creseis (Fig. 139 G). Conical, smooth, straight or flexed; circular in cross section; colorless.

Diacria (Fig. 139 C, D). Dorsoventrally inflated; aperture with hoodlike projections; dorsal lip thickened; white to brown.

Family **Limacinidae**

The shells are small and fragile, sinistrally coiled and sometimes involute. There is a thin, chitinous operculum. In *Limacina* the shells are small, sinistral, thin, and transparent.

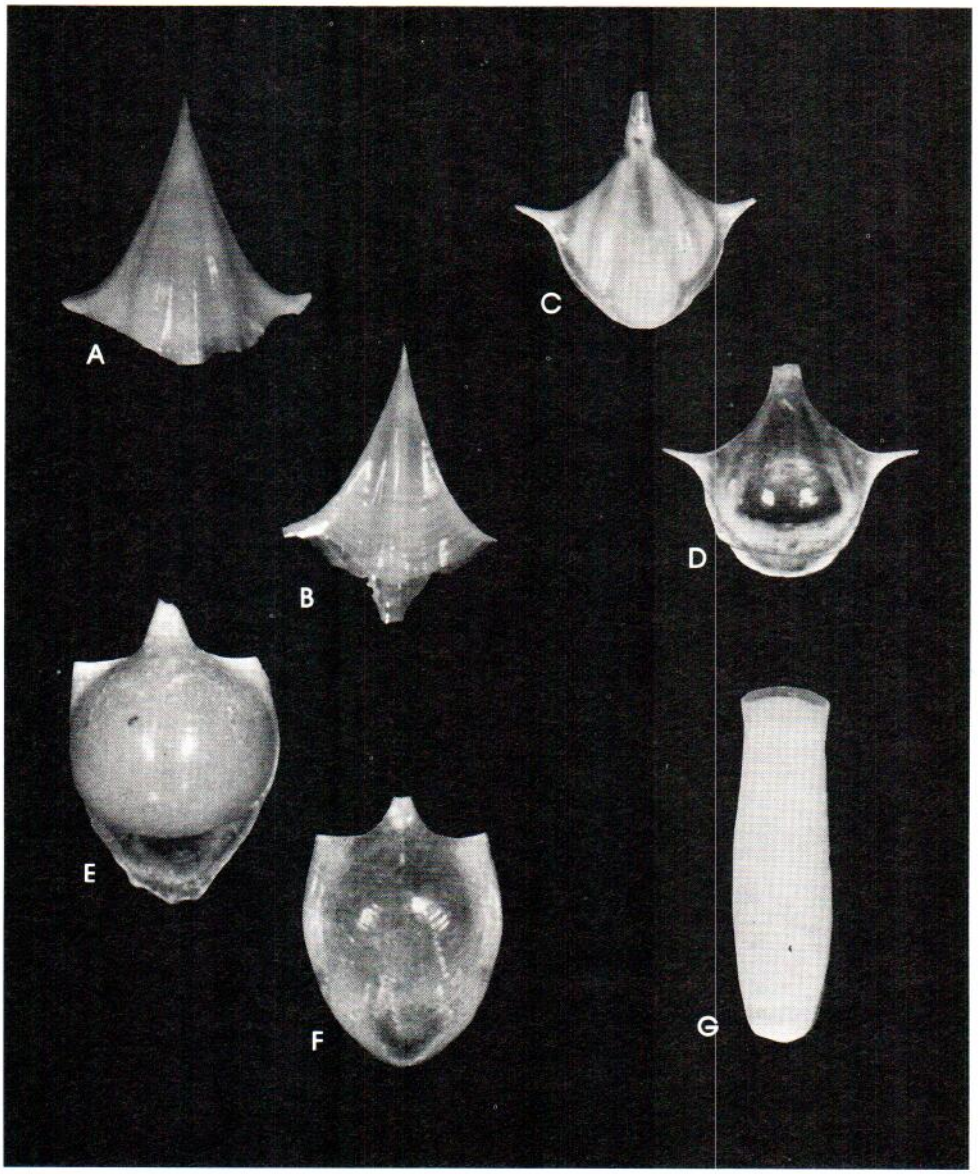


Figure 139.—Pteropods. A, B. *Clio pyramidata*, length 10 mm. C, D. *Diacria trispinosa*, length 9 mm. E, F. *Cavolinia globulosa*, length 12 mm. G. *Creseis* sp., length 4 mm.

Order ANASPIDEA

Superfamily APLYSIACEA

Family **Aplysiidae**

The Anaspidea encompasses the group of opisthobranchs familiarly known as the sea hares of the family Aplysiidae, and the Akeratidae, a group that is not represented in Hawaii. As the name of the order suggests, anaspids lack a fleshy shield.

The aplysiids are benthic, algal-feeding gastropods with plump bodies, a vestigial internal shell, and with the mantle cavity reduced to a small recess on the right side (Fig. 140 A). The foot is modified such that it forms parapodia, prominent lateral growths which are either flat or upstanding. In some forms the parapodia enable the animal to swim for short distances.

The herbivorous feeding habits of these animals confine them to the littoral and sublittoral, and few have been recorded from depths greater than 30 m. The radula consists of many similar teeth, and the alimentary canal contains a "gizzard," a sac with hard plates that triturate and strain algal food.

Aplysiids, as are other opisthobranchs, are hermaphroditic. There is an open sperm groove which runs diagonally across the right side of the animal from the common gonopore in the floor of the mantle cavity to the male pore at the base of the right tentacle. Sea hares copulate in chains in which each member acts as a male to the preceding member, and as female to the succeeding member (Fig. 131 C).

Several members of the family are conspicuous elements of the shore and shallow-water fauna of the Hawaiian Islands (Kay, 1964b). The four subfamilies and genera are keyed below:

1. Animals without a dorsocaudal disk 2
   Animals with an oblique dorsocaudal disk ..... (Dolabellinae) *Dolabella*
2. Parapodia mobile, upstanding, with or without a sucker on foot 3
   Parapodia small, tightly fastened 4
3. Dorsal slit restricted to the anterior half of the body ..... Notarchiinae *(Stylocheilus)*
   Dorsal slit of parapodia occupying more than half the length of the body ..... Aplysiinae *(Aplysia)*
4. Body thick, covered with warts ..... Dolabriferiinae *(Dolabrifera)*
   Body depressed, smooth ..... Dolabriferiinae *(Petalifera)*

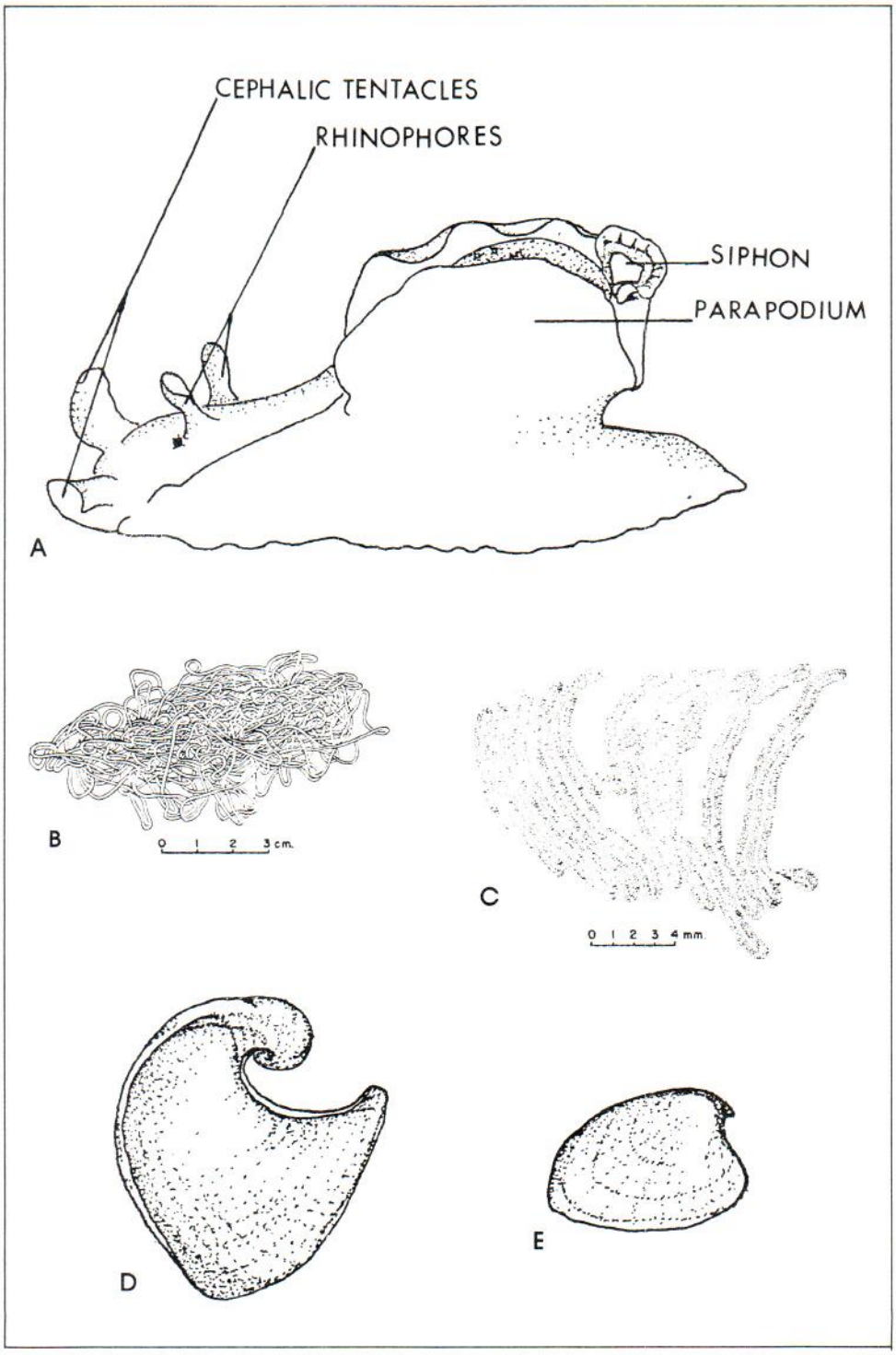


Figure 140.—**Aplysiidae.** A. *Aplysia* animal. B. *Aplysia* egg mass. C. *Dolabrifera dolabrifera* egg mass. D. *Dolabella auricularia* shell. E. *Dolabrifera dolabrifera* shell. (B and C after Ostergaard, 1950.)

Subfamily **Aplysiinae**

Aplysia dactylomela Rang, 1828. Fig. 141 A. (Synonym: *Syphonota grandis* Pease, 1860.) Length: 100 mm. *Animal:* with high, natatory parapodia; mantle covering shell completely, with a small papilla usually present in the center, siphon large, tubular and with scalloped edges; skin smooth; parapodia large, often scalloped, separate posteriorly but forming a shelf; head large and with wide, flaplike tentacles and slender, auriculated rhinophores; foot sharply differentiated, rounded anteriorly, tapered posteriorly. *Color:* rich olive-brown speckled with clusters of minute, cream-white dots and scattered, anastomosing black or brown rings and lines; parapodia streaked with black at the shoulders. *Shell:* large, heavily calcified; oval with an oblique apex and a deep anal sinus.

A. dactylomela occurs in localized areas along the shorelines where there is a gravel- or silty-sand substrate studded with *Padina* and some of the shorter red algae, the combination forming a cryptically colored background on which the animals are inconspicuous. These sea hares are most abundant between October and February. They emit a dark purple dye when disturbed.

This species is circumtropical in its distribution, recorded from the western Atlantic, east coast of Africa, tropical regions of Japan, and numerous Pacific islands (Eales, 1960), and as far south as New Zealand.

Aplysia juliana Quoy and Gaimard, 1832. Fig. 141 C, D. (Synonyms: *Syphonota bipes* Pease, 1860; *Aplysia sandvicensis* Sowerby, 1869.) Length, about 50 mm. *Animal:* plump, highest in the middle and tending to roll into a ball when disturbed; parapodia fused high posteriorly, the smooth borders lying close together so that the dorsal slit is narrow; skin smooth; mantle aperture prominent as a circular opening on the midline of the shell; head short and rhinophores and cephalic tentacles extremely contractile; foot moderately wide, rounded anteriorly, distinct from the body, and with a posterior sucker. *Color:* variable — dark green-brown with sooty blotches, white with angular black spots, fawn with sooty marks.

These sea hares are common, found under rocks in shallow (0 to 2 m) water wherever there is the green alga *Ulva*. Adult *A. juliana* grow to weights of about 60 g in Hawaii; in Japan animals weighing 450 g have been recorded (Saito and Nakamura, 1961; Sarver, 1977). The animals are nocturnal and do most of their feeding and spawning at night. The mantle glands secrete a white fluid and there is usually a distinctly musky odor associated with them.

The animals are simultaneous hermaphrodites although they function as only one sex during a particular mating (Sarver, 1977). The egg masses consist of long, tangled skeins of yellowish threads attached to the undersides of rocks and on the thallus of *Ulva* (Fig. 140 B). Mating and egg-laying occur many times during each animal's lifetime, with a single individual producing millions of eggs (Sarver, 1977). There is a planktotrophic veliger larval stage of about 30 days in laboratory culture (Switzer-Dunlap and Hadfield, 1977). The larvae settle on the thallus of *Ulva* where they spend three weeks feeding on the alga and then migrate to the adult habitat under rocks (Sarver, 1977). Mortality while on the alga is high, and fewer than two percent of the larvae survive to move to the adult habitat (Sarver, 1977). Estimated life span of these sea hares in the field is two and one-half to three months (Sarver, 1977).

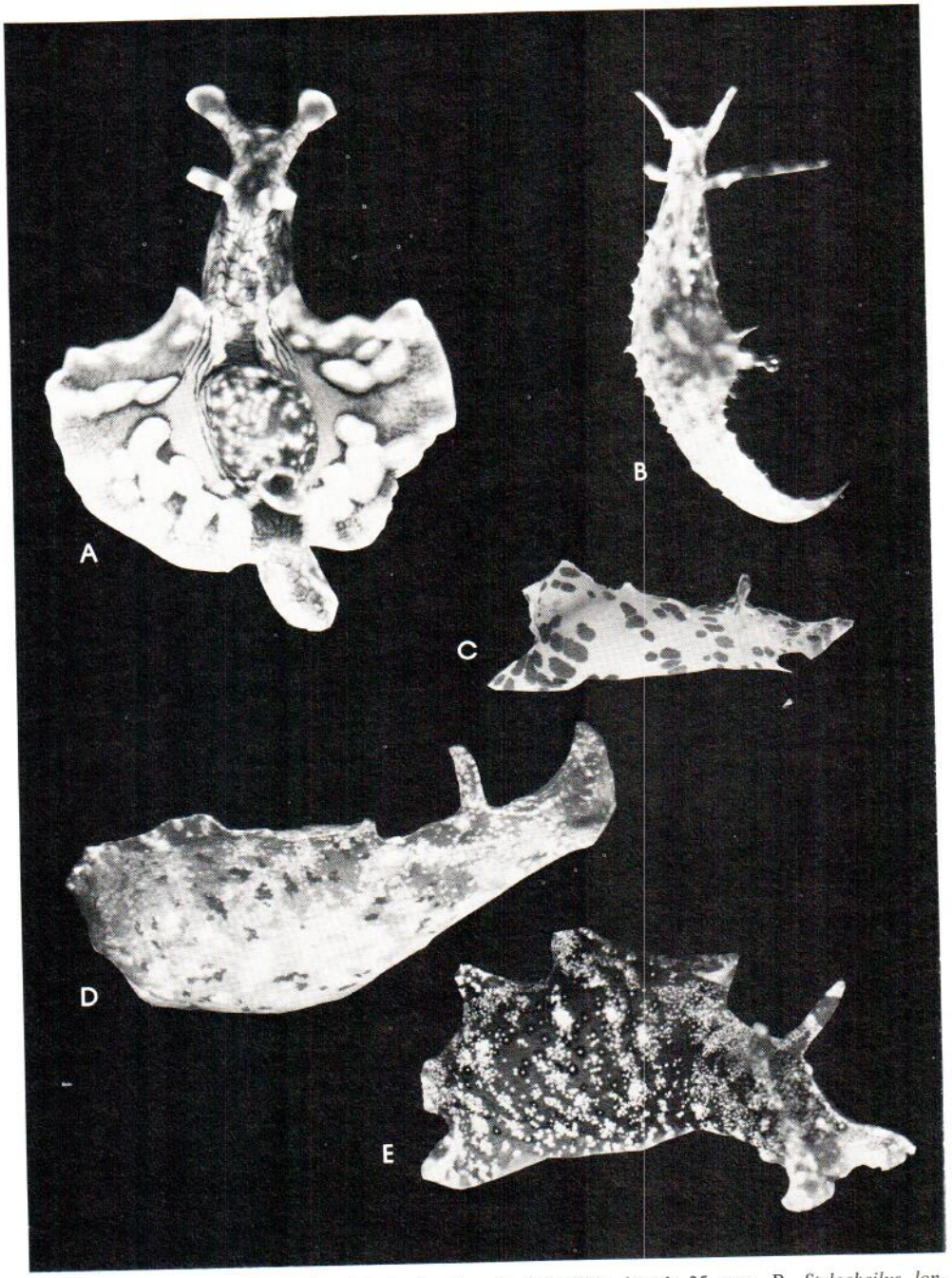


Figure 141.—**Aplysiidae.** A. *Aplysia dactylomela* (juvenile), length 25 mm. B. *Stylocheilus longicaudus*, length 20 mm. C, D. *Aplysia juliana*, (C) juvenile, length 15 mm, (D) length 30 mm. E. *A. oculifera*, length 50 mm.

A. juliana is circumtropical in its distribution, recorded from the eastern and western Atlantic (Marcus, 1956; Eales, 1960), the east coast of Africa (MacNae, 1955) and throughout the Indian and Pacific oceans (Eales, 1960).

Aplysia oculifera Adams and Reeve, 1850. Fig. 141 E. Length, 60 mm. *Animal:* plump, rather flaccid; parapodia high, ruffled at the edges and held apart so that the mantle is exposed; mantle covering the shell completely and with a small, blind papilla; skin smooth; anal siphon tubular, with a distal frilled margin; head small, the cephalic tentacles wide and frilled and the rhinophores slender and acutely pointed, set close together and slit more than half-way down. *Color:* olive-green usually speckled profusely with cream-colored dots and numerous, scattered, well-defined, small (1 mm) black ocellae, which are usually centered with white. *Shell:* oval, distinctly concave, lightly calcified; apex small and pointed; anal sinus broad and shallow.

A. oculifera is a rather uncommon species, usually found on the frontal edges of limestone benches exposed to considerable wave action.

Eales (1960) records *A. oculifera* from the Red Sea, Pakistan, East Indies, and Western Australia; and Baba (1936) records it from the Ryukyu Islands (as *Tethys hirasei*).

Aplysia parvula Guilding in Mörch, 1863a. Fig. 131 C. (Synonym: *Syphonota elongata* Pease, 1860.) Length, 19 mm. *Animal:* short and plump; parapodia short, widely separated anteriorly and forming a narrow shelf around the mantle cavity posteriorly; mantle thin, with a large, oval foramen which exposes about one-third of the shell; skin smooth; anal siphon long and tubular; head small and neck extensible; cephalic tentacles broad at the base, tapering distally; rhinophores small, slender and slit two-thirds their length; foot wide and capable of curling around the stipes of algae, rounded anteriorly and tapering into a slight tail. *Color:* variable — dark brown with cream-colored reticulations on the parapodia and cream-colored appendages; light fawn; velvet black. *Shell:* oval, strongly convex with a deep anal siphon and distinct spire.

Apparently never abundant, specimens of *A. parvula* are found in sheltered shoreward pools on benches and shoreward of fringing reefs. The animals may be buried in the sand-algal mat on small stones and coral rubble or entangled in strands of the algae *Sargassum, Spyridia,* and *Hypnea.* Quantities of purple dye are produced when the animals are disturbed. They spawn a typical aplysiid egg mass of long, light-green threads which are attached to the sides of loose rocks on the substrate.

A. parvula is circumtropical in distribution, recorded from Devon, England (Bebbington and Brown, 1975), the tropical western Atlantic (Engel, 1927; Marcus, 1956), through the Indian and Pacific Oceans (Eales, 1960), as far south as New Zealand (Morton and Miller, 1968), and as far east as the Gulf of California (Marcus and Marcus, 1967b).

Aplysia pulmonica Gould, 1852. (Not figured.) *Animal:* slender, oval; parapodia set high, short with smooth edges, widely spaced anteriorly and forming a low shelf posteriorly; mantle exposed, covering the shell completely and with a small papilla, anal siphon tubular and scalloped; skin smooth; head small, neck short and thick, with

broad, flaplike cephalic tentacles and slender, partially slit rhinophores; foot distinct, rounded anteriorly and tapered posteriorly. *Color:* bronze-green, densely speckled with white and reticulated with black. *Shell:* small, calcareous, flat; apex oblique, spire lacking; anal sinus bordered by a thickened margin.

This is a rarely and sporadically encountered species in Hawaii. Animals have been found on the frontal slope of solution benches and at the seaward edge of a fringing reef on Kauai, and in Kaneohe Bay, Oahu (Watson, 1973).

A. pulmonica has been recorded from "South-east Asia, islands in the South Pacific (Samoa, Hawaii, etc.) and Australia" (Eales, 1960).

Subfamily **Notarchiinae**

Stylocheilus longicaudus (Quoy and Gaimard, 1824). Fig. 141 B. (Synonyms: *Stylocheilus lineolatus* Gould, 1852; *Aclesia areola* Pease, 1860; *Notarchus striatus* (Quoy and Gaimard) Ostergaard, 1950.) Length: 27 mm. *Animal:* elongate, cylindrical; parapodia short, closely approximated anteriorly and posteriorly, the dorsal slit less than one-quarter the length of the body; skin with numerous scattered villi which stud the parapodia, rhinophores and cephalic tentacles; head small and retractile into the body; cephalic tentacles and rhinophores long and slender and with pendent oral lobes joined to the cephalic tentacles; foot distinctly separate from the body, the anterior margin rounded and bilabiate. *Color:* longitudinal gray-brown striations interrupted by yellow-ringed ocelli with blue or black centers.

S. longicaudus is an abundantly occurring species with swarms of thousands of individuals appearing about twice a year, in June and July and again in October and November. They are found in most shallow water areas around the Hawaiian Islands, on benches and in shallow areas shoreward on fringing reefs where they are associated with the blue-green alga *Lyngbya*. The egg masses consist of tangled skeins of cream-white or orange-yellow strands.

This species is circumtropical and has been recorded from the tropical western Atlantic as well as from the Indo-West Pacific (Engel, 1936).

Subfamily **Dolabellinae**

Dolabella auricularia (Lightfoot, 1786). Figs. 140 D; 142 C. (Synonyms: *Dolabella variegata* Pease, 1860; *D. hasseltii* Ferrusac, MacFarland, 1918; *D. scapula* (Martyn), Engel, 1942.) Length: up to 200 m. *Animal:* plump and heavy with a small *Aplysia*-like head and a disklike posterior end; parapodia low, fused to the body and flaring into an elongate aperture at their termination posterior to the midline of the body and a circular aperture on the posterior disk; skin with irregular warts and tubercles; large, auriculate cephalic tentacles and smaller, conical rhinophores; disk separated from the body by a fringe of irregular lobes, with a narrow dorsal slit; foot continuous with the sides of the body. *Color:* dark green mottled with black and brown and finely speckled with white. *Shell:* large, solid, convex on the dorsal surface with a strongly curved and callous spire and deep anal sinus.

D. auricularia occurs mainly on silty, sand substrates in protected bays and shoreward on fringing reefs, where there is a heavy growth of *Padina* and other brown and red algae; specimens are common at depths of from 15 cm to 1 m from January through March.

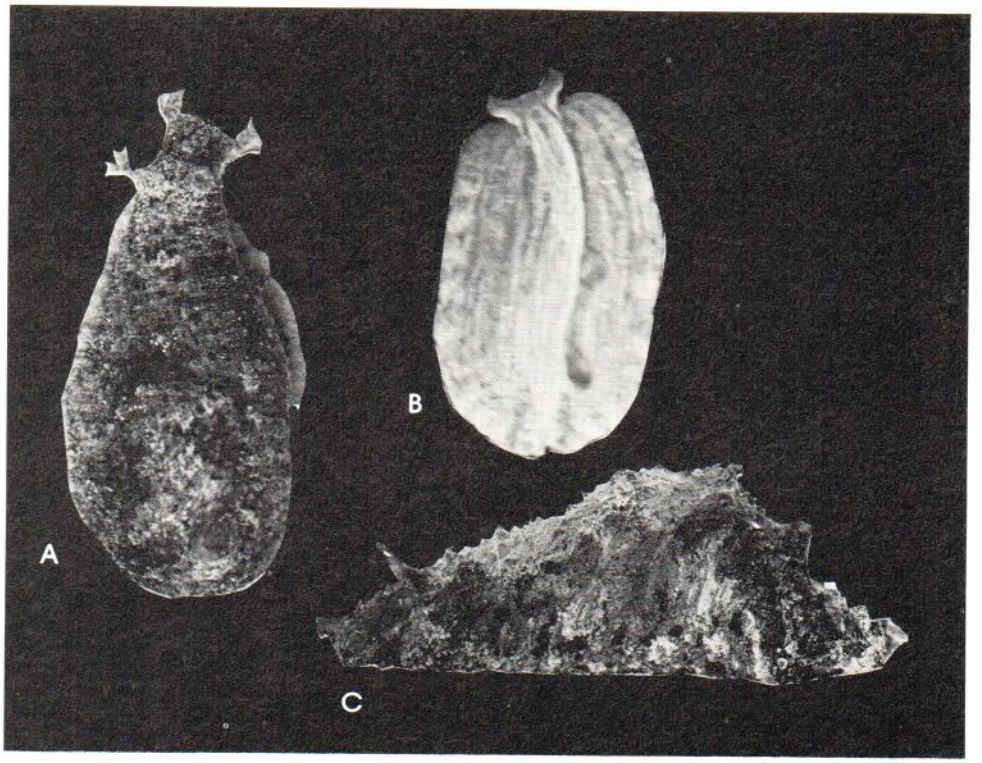


Figure 142.—A. *Dolabrifera dolabrifera*, length 35 mm. B. *Petalifera petalifera*, length 20 mm. C. *Dolabella auricularia*, length 100 mm.

This species is circumtropical in distribution, found in the eastern and western Atlantic and throughout the Indo-West Pacific (Engel, 1942).

Subfamily **Dolabriferiinae**

Dolabrifera dolabrifera (Rang, 1828). Figs. 140 C, E; 142 A. (Synonyms: *Aplysia oahuensis* Souleyet, 1852; *Dolabrifera olivacea* Pease, 1860; *Dolabrifera marmorea* (Pease), Sowerby, 1868.) Length, 40 mm. *Animal:* pyriform; parapodia closely applied to the body, the right overlapping the left and opening only on the posterior half of the body; mantle cavity open at both ends; skin warty and rough, the pustules with microscopic, transparent, branched filaments; rhinophores and cephalic tentacles smooth, simply rolled and slit two-thirds their length, the distal ends terminating in flaring cups; foot bifid anteriorly and with lateral shoulders. *Color:* varied — mottled gray-green and brown, dark brown, light red, or cream-colored. *Shell:* small, triangular, hidden beneath the mantle under the left parapodium.

D. dolabrifera is abundant throughout the year. The animals live on the undersurfaces of rocks and rubble at the shoreward edge of limestone and basalt benches and in the shallow waters inshore of fringing reefs. The eggs are deposited in transparent zigzags on the undersurfaces of rocks.

D. dolabrifera occurs in the eastern and western Atlantic, throughout the Indo-West Pacific (Engel, 1936), and in the eastern Pacific (Bertsch, 1970).

Petalifera petalifera (Rang, 1828). Fig. 142 B. Length: up to 25 mm. *Animal:* pyriform to elliptical; parapodia short, narrow, unequal, exposing the shell; dorsal slit one-half the length of the body, on the right; skin soft, sparsely decorated with fine, branched, transparent papillae; head small and narrow, the visceral mass humped posteriorly; cephalic tentacles truncated, rhinophores long and slender, and with a pair of auriculate oral lobes; foot short and broad, lateral borders thin and undulated forming the anterior lip, medially thickened and depressed forming the posterior lip. *Color:* cream-brown to yellow-green with alternating rows of small red spots and white stripes, one white stripe more prominent than the others and extending from the right cephalic tentacle across the dorsum to the mantle cavity. *Shell:* aplysiiform, delicate, transparent white; apex curved with a distinct spiral and noticeable anal sinus.

These aplysids are rarely encountered. They apparently live on the alga *Padina* on which they are almost invisible, their flattened, elliptical shape conforming to the curve of the blade and their color pattern matching almost exactly that of the alga.

P. petalifera has been recorded from the Mediterranean, West Indies, and through both the Indian and Pacific Oceans (Engel, 1936).

Order NOTASPIDEA

There are two superfamilies in this order, the Pleurobranchacea with an internal shell or no shell, and the Umbraculacea with a large, limpetlike shell which sits atop the body of the animal. The gill is naked, on the right side where it is overhung by the mantle skirt.

Superfamily PLEUROBRANCHACEA

Family **Pleurobranchidae**

Pleurobranchids are rather flat, sluglike opisthobranchs with the mantle covering the dorsal surface and projecting around the animal like a skirt. There is an oral veil, a frontal expansion of the mantle distinctly marked off from the rest of the body. Enrolled rhinophores extend anteriorly from beneath the mantle skirt. An internal shell is often present, and there is also a pronounced metapodial gland in the foot of some animals. The appearance of the metapodial gland may mark the commencement of the breeding period in some forms (Thompson and Slinn, 1959), and in *Berthellina citrina* in Tanzania the shell may disappear toward sexual maturity when the metapodial gland develops (Edmunds and Thompson, 1972). In all pleurobranchids examined, the skin secretes a strong acid secretion when the animal is disturbed (Thompson, 1970; Edmunds and Thompson, 1972).

The genera are distinguished by the shape of the mantle, the form of the gill, and differences in radula and genitalia:

1. Mantle smooth 2
   Mantle tuberculate; gill rachis with alternating tubercles ..... *Pleurobranchus*
2. Mantle skirt large; gill rachis without tubercles 3
   Mantle skirt narrow; oral veil with anterior ventral papillae ..... *Euselenops*
3. Radular teeth hook-shaped ..... *Berthella*
   Radular teeth elongate ..... *Berthellina*

Berthella pellucida (Pease, 1860). (Not figured.) Length to 20 mm; width to 11 mm. *Animal:* ovate, smooth, mantle colorless and transparent with minute reticulations of pale brown, the brown digestive gland and ovotestes clearly visible. *Tentacles:* united for about half their length, enrolled. *Gill:* pinnate, with the rachis separate and

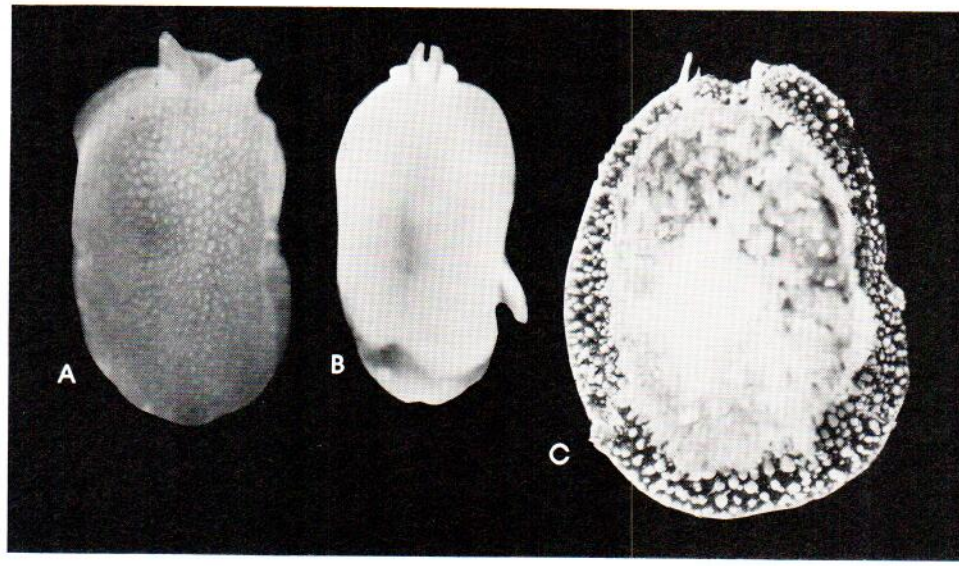


Figure 143.—A. *Pleurobranchus peronii*, length 40 mm. B. *Berthellina citrina*, length 30 mm. C. *Umbraculum sinicum*, length 72 mm.

feathery. *Shell:* internal, delicate, proportionately large and covering the whole visceral mass, extending nearly the length of the animal.

Because of the small size and rather nondescript appearance of these pleurobranchids, records of *B. pellucida* are rare. In Hawaii animals have been recorded from October to January. All were found under rocks on benches subject to considerable water movement.

B. pellucida was described from the Hawaiian Islands and has been recorded from New Caledonia (Risbec, 1928) and Queensland, Australia (Thompson, 1970).

Berthellina citrina (Ruppell and Leuckart, 1831). Fig. 143 B. (Synonym: *Pleurobranchus delicatus* Pease, 1860; Edmondson, 1946.) Length to 35 mm; diameter to 20 mm. *Animal:* ovate, smooth, bright orange. *Tentacles:* united near the base, enrolled. *Gill:* pinnate, with about 24 pinnules on each side of the rachis, the free tip of the gill constituting more than one-third of the gill length; anal papilla at the level of the rear of the gill mesentery. *Penis:* simple, without conspicuous flaps. *Shell:* present or absent.

This is the most frequently encountered pleurobranch in Hawaiian waters, found under loose rubble on rocks where there is considerable water movement. Specimens have been recorded in all months of the year.

B. citrina has been recorded from many localities in the Indo-West Pacific from the Red Sea to Palau and Japan (see Thompson, 1970, for summary), and from the Mediterranean coast of Israel (Eales, 1970).

Euselenops luniceps (Cuvier, 1817). Fig. 131 D. Length, 60 mm; diameter, 45 mm. *Animal:* broadly oval, smooth; the foot extending broadly beyond the animal on

both sides; mantle smooth, pale lavender with conspicuous brown-red blotches and with a midposterior crenulation which forms a siphon in life. *Tentacles:* rhinophores white, ringed with brown, originating from the head close to the anterior margin of the mantle; short anterolateral tentacular projections on the broad oral veil and numerous small white papillae on ventral surface. *Foot:* sole white; dorsal surface colored like the mantle. *Gill:* with a double row of alternating tubercles along the rachis. *Shell:* absent.

These animals are sand-dwellers and are infrequently found in sandy pockets on fringing reefs. They lie partially buried in sand, the rhinophores and posterior siphon showing above the surface, the siphon pulsating so that the animal may be mistaken for a small octopus. Previous figures of the animal (Bergh, 1905; Baba, 1955; Thompson, 1970) show only a posterior mantle crenation, but in life the mantle forms a distinct siphon posteriorly, as shown by Pace (1901). They swim vertically, much as does *Hexabranchus*.

E. luniceps has been recorded from South Africa (O'Donoghue, 1930), Ceylon (White, 1947), India (Satyamurti, 1946) and Australia (Allan, 1950; Thompson, 1970).

Pleurobranchus peronii Cuvier, 1804b. Fig. 143 A. Length, to 60 mm; width, 20 mm. *Animal:* ovate; mantle irregularly, faintly mamillate; ground color orange-red to red-brown with a pattern of closely fitting polygonal dark orange-red markings some of which may have a central yellow spot; mantle deeply sinuate midanteriorly. *Rhinophores:* beneath mantle sinuation, enrolled. *Gill:* rachis with an alternating double row of tubercles; anal papilla situated above the posterior end of the gill mesentery. *Penis:* moderately slender with a prominent triangular flap at the base. *Foot:* with a pedal gland. *Shell:* present or absent.

These pleurobranchs are uncommon, found under rocks and rubble in shallow bays.

P. peronii is apparently widely distributed in the Indo-West Pacific, recorded from South Africa, eastern Australia and Palau (Thompson, 1970).

Pleurobranchus violaceus Pease, 1864. (Not figured.) (Synonym: *Pleurobranchus reticulatus* Pease, 1860, non Rang, 1832.) Length, to 80 cm; diameter, 40 cm. *Animal:* oval, convex dorsally; mantle deeply sinuate anteriorly, rounded posteriorly; mantle crowded with depressed tubercles with angulated bases; pale cream to lavender reticulated with darker purple. *Rhinophores:* large, truncate. *Gill:* simple, pinnate; free half its length and with two alternating rows of granules. *Shell:* not known.

These pleurobranchs are the largest representatives of the family in Hawaii. They are apparently fairly common at depths of about 30 m and are infrequently seen on fringing reefs at night.

P. violaceus was described from the Hawaiian Islands.

Additional Records

Three pleurobranchids described from the Hawaiian Islands by Pease (1860) were so insufficiently detailed that they cannot be identified with certainty: *Pleurobranchus marginatus, P. rufus,* and *P. varians.*

Family **Umbraculidae**

The umbraculids, known popularly as the umbrella shells, are distinguished by a large, patelliform shell covered with a beardlike periostracum which sits over a massive, tuberculate foot. The body is much larger than the shell, and there is a pair of enrolled rhinophores on the head.

Umbraculum sinicum (Gmelin, 1791). Figs. 134 I; 143 C. (Synonym: *Operculatum aurantium* Pease, 1868b.) Length, 72 mm; diameter, 60 mm. *Shell:* external; strongly calcified; apex blunt and central; white. *Animal:* mantle inconspicuous, lying beneath the shell; two pairs of cephalic tentacles above the mouth; rhinophores enrolled, with the bases and the eyes, which lie below them, hidden by the shell in life; foot massive, with anterior and posterior notches; sole broad and flat, dorsal and lateral surfaces with large, soft, nonretractile tubercles decreasing in size toward the periphery. *Color:* variable — gray-brown, studded with white tubercles, pale yellow, bright orange with white pustules.

These opisthobranchs are common, found beneath ledges and in crevices on basalt shorelines and on solution benches where there is considerable water movement.

Burn (1959) suggests that most published records of *Umbraculum* relate to a single circumtropical species. In South Africa they lie half buried in the uppermost soft layers of the muddy substratum during the day (MacNae, 1962). Abbott (1974) says that *Umbraculum umbraculum* of the Atlantic feeds on sponges.

Order SACOGLOSSA

The name of this order derives from the sac or ascus in which used radular teeth accumulate. The radula is composed of a single file of sharp-pointed teeth, only one of which is functional at a time. The radula and a muscular buccal "pump" are features peculiar to this group of opisthobranchs, as is the presence in some of algal chloroplasts, derived from the algal food, in the cells of the digestive gland. The chloroplasts may impart a brilliant green color to parts of the animals. Most sacoglossans feed on siphonous green algae such as *Caulerpa* and *Codium,* but in one family, the Oleidae (not known in Hawaii), the radula is used in piercing the eggs of opisthobranchs.

Sacoglossans include both shelled and sluglike forms. The Oxynoacea have thin, spirally coiled shells, the Juliacea (the bivalved gastropods) have divided or bivalved shells; and the Plakobranchacea lack shells. The digestive gland forms a single mass in the shelled forms, but ramifies as tubules which line the parapodia of the plakobranchids, and extend into cerata in the Hermaeidae. Most sacoglossans are small (3.5 to 40 mm) in Hawaii, and they are rather elusive creatures, often cryptically colored and well hidden in the algae on which they feed. Their egg masses are transparent, gelatinous flattened coils which are often deposited on the stipes of the algae among which they live.

Superfamily OXYNOACEA

Family **Oxynoeidae**

These sacoglossans have thin, spirally coiled shells which are inadequate to contain even the retracted animal. The parapodia cover the shell in life. They are undivided in *Oxynoe,* bilobed in *Lobiger.*

Lobiger souverbiei P. Fischer, 1856. Fig. 144 D. Length, 10 mm; diameter, 7 mm (of shell). *Shell:* oval, cap-shaped; margins free on all sides; with a remnant of coiling internally. *Animal:* enclosed in a cap-shaped shell from which emerge two pairs of narrow, projecting parapodial lobes and a pronounced tail; head small, rhinophores rolled their entire length and tapering at the tips, the anterior median edges overlapping the outer edge and flaring near the base into lobes on either side of the mouth; parapodial lobes flat, spatulate, with wide, squared-off tips, the edges deeply scalloped and in-rolled; foot rounded, extending under the lobes of the rhinophores and tapering posteriorly; parapodia and exposed body covered with prominent tubercles. *Color:* pale

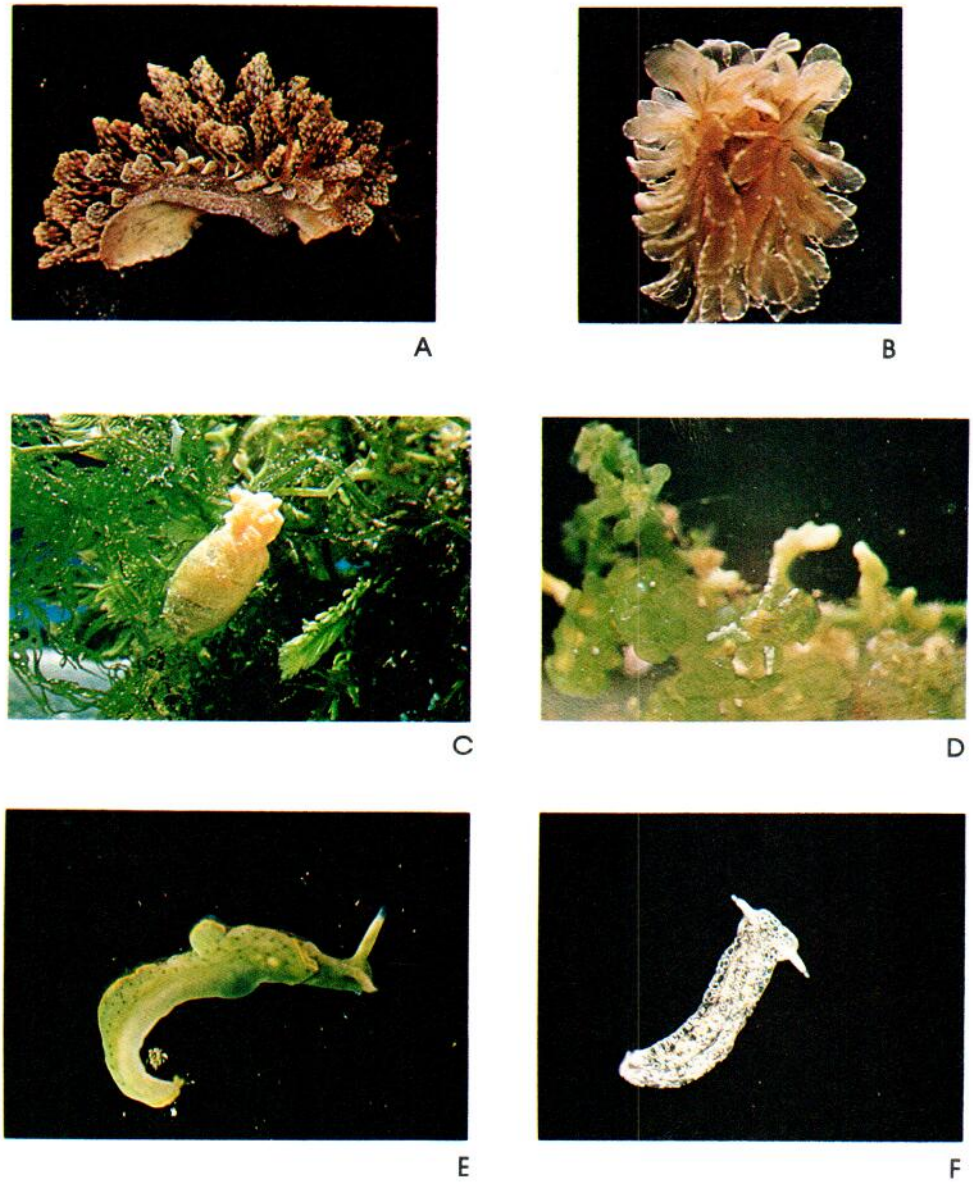


Figure 144.—Sacoglossans. A. *Cyerce nigricans*, length 30 mm. B. *C. elegans*, length 30 mm. C. *Volvatella pyriformis*, shell length about 10 mm. D. *Lobiger souverbiei*, shell length about 10 mm. E. *Elysia lobata*, length 15 mm. F. *Plakobranchus ocellatus*, length 30 mm. (C by O. Schoenberg.)

jade-green, the parapodia with a diffuse band of orange-pink which is darker on the inner surface than the outer; tubercles tipped with yellow; mantle under the shell green and axially streaked with dark blue.

L. souverbiei occurs on the siphonous green alga, *Caulerpa racemosa* var. *turbinata* (J. Ag.) Eubank, 1946. The animals lie near the top of dense masses of the alga with the foot and body closely applied and the parapodial lobes elevated. When disturbed they emit a white fluid. Associated with *L. souverbiei* in the same clumps of *Caulerpa* are two other sacoglossans, *Berthelinia pseudochloris* Kay, 1964a, and *Elysia* aff. *cauze* Marcus, 1957. Specimens of *L. souverbiei* have been found in almost every month of the year, but only one or two specimens have been noted on any single occasion.

L. souverbiei appears to be circumtropical in distribution; it was described from the West Indies, and also occurs in Brazil on *Caulerpa racemosa* (Marcus, 1957). Baba (1974) records it from Sagami Bay, Japan, and Sphon (1971) from Santa Cruz (Mexico).

Additional Records

Two species referable to *Oxynoe* have been reported from the Hawaiian Islands, but there are no recent records of these animals. *Lophocercus krohnii* A. Adams, 1855d, which was described from the Islands, has a light, thin, white, cap-shaped shell typical of *Oxynoe*. *Oxynoe (= Lophocercus) viridis* Pease (1861c) was recorded from the "Sandwich Islands" by Mörch (1863b).

Family **Volvatellidae**

In the Volvatellidae the shell is bulloid, the margins meeting midventrally and forming a spout at the posterior end. The coiled portion of the shell is sunk in the left margin. The paired rhinophores and oral lobes of the animals are much flattened compared with those in *Lobiger*, *Berthelinia*, and *Julia*.

Volvatella fragilis Pease, 1860. (Not figured.) Length, 8 mm; diameter, 4 mm. *Shell:* ovate, broadest in the middle and contracting as a spout; thin and fragile. *Animal:* as in *V. pyriformis*. *Color:* white.

These sacoglossans are occasionally found on *Caulerpa* in Kaneohe Bay, Oahu.

V. fragilis was described from the Hawaiian Islands.

Volvatella pyriformis Pease, 1868c. Fig. 144 C. (Synonym: *Arthressa* [*sic*] *evansi* Kay, 1961c.) Length, 11 mm; diameter, 5 mm. *Shell:* globose-ovate, broadest in the middle and contracting posteriorly as a spout; thin and fragile. *Animal:* head and foot protruding from the shell; cephalic shield short and truncate, the corners produced as tentacles; rhinophores posterior to the oral lobes, grooved and blunt; foot triangular with blunt corners. *Color:* orange, freckled with a darker shade and with a band of red-orange freckling crossing the visceral mass; foot pale.

Three or four animals have been found embedded in algal mats on solution benches on Oahu, others were on *Caulerpa*.

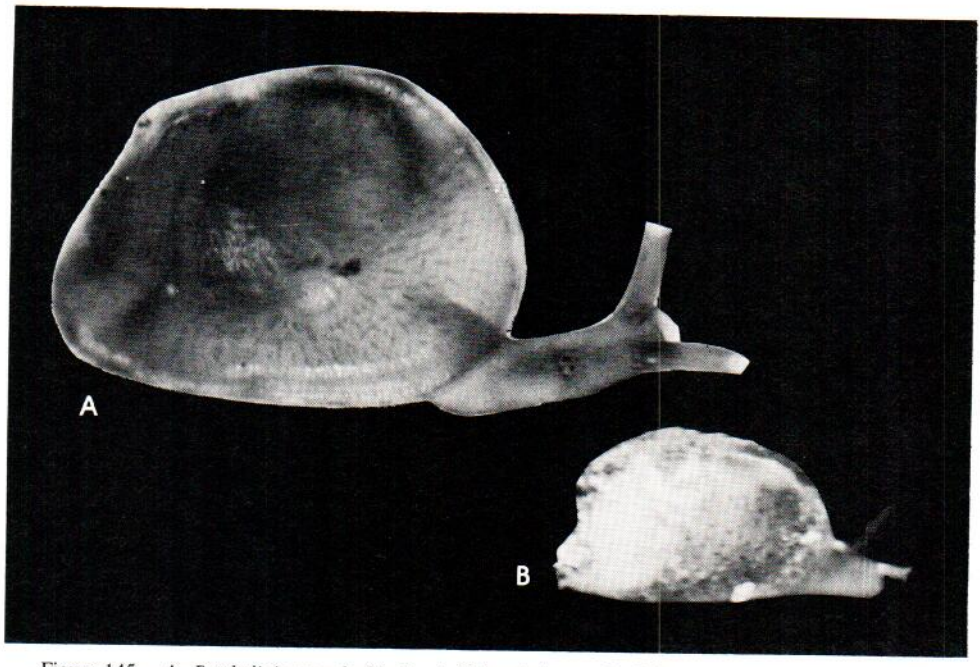


Figure 145.—A. *Berthelinia pseudochloris*, shell length 4 mm. B. *Julia exquisita*, shell length 3 mm.

V. pyriformis was described from Tahiti. *Arthessa evansi* Kay, 1961c, was distinguished because of Evans's (1950) distinction between the genera *Volvatella* and *Arthessa*, but there now seems no reason to distinguish the two genera.

Superfamily JULIACEA

Family **Juliidae**

This group of opisthobranchs comprises the bivalved gastropods, animals with sluglike bodies enveloped by two shell valves. Single valves have been known since 1862, and, because of their obvious bivalve appearance, classified in the Bivalvia. Kawaguti and Baba described the living animals in 1959; sacoglossan slugs bearing two valves, one on each side of the body.

Berthelinia pseudochloris Kay, 1964a. Fig. 145 A. Length, 4 mm; height, 3 mm; diameter of both valves, 1.5 mm. *Shell:* ovate-trigonal, rounded anteriorly and posteriorly, narrowed posteriorly with the dorsal posterior edge in a straight line; thin; protoconch of one and one-half whorls, sharply set off from the rest of the shell and inclined nearly horizontally in adult specimens; hinge with one strong and one weak tooth posteriorly. *Color:* translucent green, protoconch white and pearly. *Animal:* sluglike, head and neck slender, rhinophores with parallel sides; leaf-green ornamented with minute opaque white spots on the oral tentacles, rhinophores and foot, the head

and neck microscopically speckled with brown; mantle with red pigment which radiates through the shell and bands the shell ventrally, alternating with splashes of white.

B. pseudochloris is found with *Elysia cauze* and *Lobiger souverbiei* on the green alga *Caulerpa;* it is not common, and no more than a dozen animals have been collected.

B. pseudochloris was described from the Hawaiian Islands.

Julia exquisita Gould, 1862. Fig. 145 B. Length, 3.5 mm; height, 2 mm. *Shell:* broadly oval; anterior margin rounded, posterior margin deeply excavated; sculpture of incremental lines only; hinge consisting of a shelf with a posterior toothlike knob on the left valve and a depression in the right valve; bright green with narrow, radiating interrupted bands of red-brown and white extending from the hinge to the ventral margin. *Animal:* sluglike, body long and slender, the foot nearly as wide as the neck; rhinophores slender, squared off at the tips; anterior edge of foot bilabiate and sole grooved with fine ridges its entire length; dark green sparsely ornamented on the neck and foot with small white patches ringed with brown and with similar, more prominent patches on the rhinophores, mantle with horizontal brown and white bands at the hinge line.

Few living animals have been found; they feed on *Caulerpa ambigua* but spawn on *Microdictyon* (Kawaguti and Yamasu, 1966, as *J. japonica).*

J. exquisita is apparently widely distributed in the Indo-West Pacific; shells from the Seychelles in the Indian Ocean and the Kermadec Islands off New Zealand are comparable with the Hawaiian shells.

Superfamily PLAKOBRANCHACEA

Family **Plakobranchidae**

In this family the body is elongate and the parapodia form folds which meet middorsally. The parapodia contain both diverticulae of the digestive gland and algal chloroplasts, the latter often imparting a bright green color to the animals. Between the parapodia there is a cardiac protuberance, the "heart," a saclike or tubular structure. The surface of the body is typically smooth, but the skin contains numerous glands which may form transitory pustules.

The family is represented in the Hawaiian Islands by two genera: *Plakobranchus,* in which the parapodia lie flat against the dorsoventrally compressed body; and *Elysia* (sometimes assigned to a separate family, the Elysiidae), with upstanding, winglike parapodia.

Elysia sp. cf. *cauze* Marcus, 1957. Fig. 146 D. Length, 15 mm; parapodial height, 11 mm. *Animal:* slender, leaflike; parapodia large and when held upright forming three distinct "chimneys"; rhinophores short and blunt; body covered with fine, branching, transparent papillae; pericardial prominence anteriorly rounded and tapering as a long tube posteriorly. *Color:* variable — yellow- to brown-green with

splashes of flake-white and minute, dark brown spots; parapodia occasionally edged with orange-pink; foot and head dark green, the foot speckled with white.

These elysiids live near the base of dense masses of *Caulerpa racemosa* var. *turbinata* (J. Ag.) Eubank with *Lobiger souverbiei* and *Berthelinia pseudochloris* (Kay, 1964a).

E. cauze was described from Brazil.

Elysia degeneri Ostergaard, 1955. Fig. 146 E. Length, 12 mm; parapodial height, 3 mm. *Animal:* parapodial folds low, thrown into about four lobes; rhinophores short, stout, cylindrical, anterolaterally directed; pericardial prominence anterior, close to the head. *Color:* pale green or yellow-white, mottled with darker green; inner margin of parapodial folds orange; rhinophores fawn, reticulated with green and tipped with blue-violet.

These elysiids are found on benches subject to considerable surf action and in shallow waters shoreward of fringing reefs on Oahu and Kauai. They feed and settle on the alga *Udotea* (Switzer-Dunlap, pers. comm.).

E. degeneri was described from Waianae, Oahu.

Elysia halimedae MacNae, 1954. (Not figured.) Length, 7 mm; diameter, 3 mm. *Animal:* oval; parapodia subrectangular, short, thick, and closely applied to the body; rhinophores large, auriculate, capable of retracting into a slight depression on the side of the head; foot divided into two sections by a furrow. *Color:* yellow-green, crowded with dark green spots and minutely speckled with white; rhinophores tipped with a belt of minute white spots.

These elysiids live on the green alga *Halimeda discoidea* on which they are almost invisible. Their yellow-green color is of the same hue as is the seaweed, and the minute white spots match almost exactly the calcareous spots present in the alga.

E. halimedae was described from South Africa, where it occurs on *Halimeda cuneata;* it has also been reported from Japan (Baba, 1957).

Elysia lobata (Gould, 1852). Fig. 144 E. (Synonym: *Elysia elsiae* Ostergaard, 1955.) Length, 15 mm; parapodial height, 5 mm. *Animal:* parapodia carried upright, with two or three undulations; rhinophores long and slender, grooved their entire length and usually curving anterolaterally; skin smooth or with glandular pustules, occasionally with villi. *Color:* pale blue-green, the surfaces of the body and parapodia crowded with black and white spots, occasionally with black ocelli; parapodia margined with pink, sometimes edged with yellow; rhinophores pink, tipped with blue.

This is the commonest species of elysiid in Hawaiian waters and one to ten animals can be collected monthly throughout the year. These gastropods are found under rocks on benches where there is considerable surf action, and in shallow waters shoreward of fringing reefs.

E. lobata was described from the Hawaiian Islands and is also recorded from the Marshall Islands (Marcus, 1965).

Elysia nealae Ostergaard, 1955. Fig. 146 B. Length, 21 mm; parapodial height, 3 mm. *Animal:* parapodia low, folded several times; rhinophores short relative to the

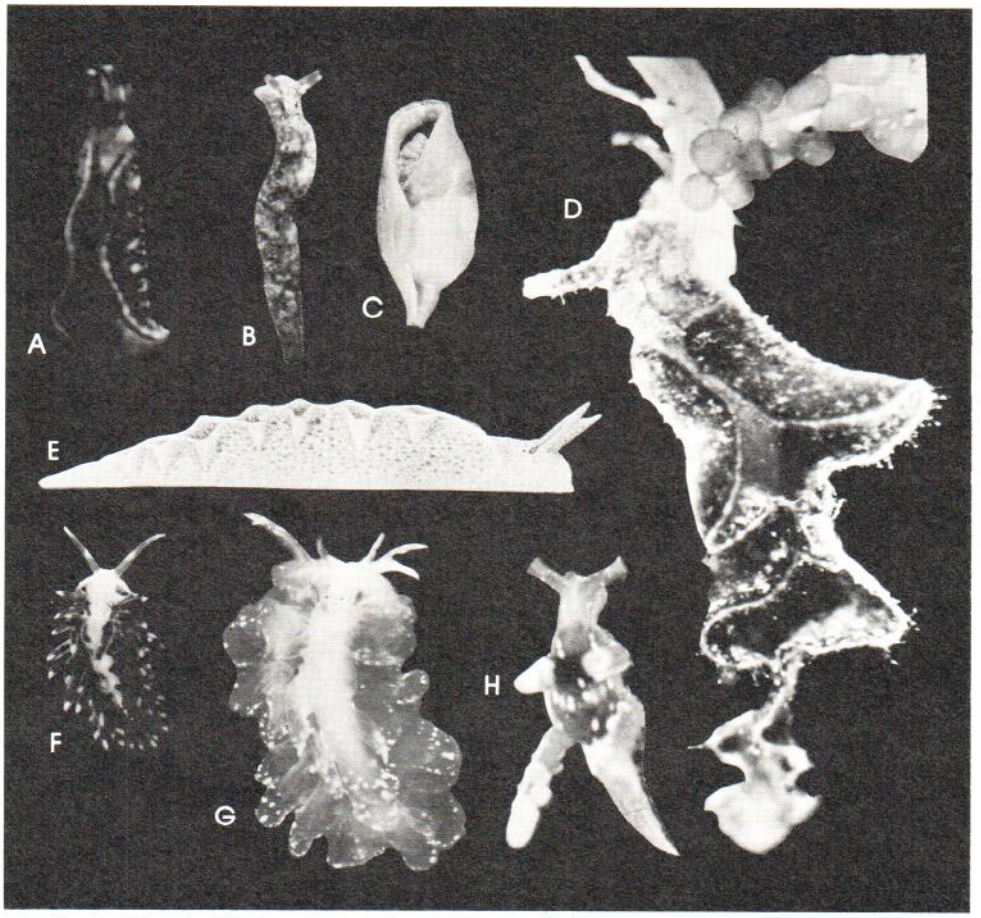


Figure 146.—A. *Elysia rufescens*, length 11 mm. B. *E. nealae*, length 20 mm. C. *Volvatella pyriformis*, shell length 10 mm. D. *Elysia* sp. cf. *cauze*, length 15 mm. E. *E. degeneri*, length 10 mm. F. *Stiliger* sp., length 6 mm. G. *Branchophyllum pellucida*, length 15 mm. H. *Lobiger souverbiei*, shell length 10 mm. (E. after Ostergaard, 1955.)

length of the animal, grooved their entire length, truncate. *Color:* green, sole and lower part of parapodia light green, parapodia becoming darker green and flecked with white toward the edges.

The holotype was found on the reef at Waikiki, Oahu. Other specimens have been recorded from Kaimalino, Oahu, and Koloa, Kauai.

E. nealae was described from the Hawaiian Islands.

Elysia ornata (Pease, 1860). (Not figured.) Length, 21 mm; parapodial height, 4 mm. *Animal:* parapodia carried upright, with three or four undulations; rhinophores grooved their entire length, truncate. *Color:* gray spotted with black and with splashes of yellow; parapodia margined with orange and edged with black, occasionally with white spots; rhinophores orange-brown and edged in black, with occasional yellow spots, tipped with brown.

Although this is a spectacular, rather large species in the genus, only four animals have been seen in recent years, all in a shallow bay shoreward of a fringing reef near Koloa, Kauai.

E. ornata has been recorded from the Sulu Sea (Bergh, 1905) New South Wales (Allan, 1947 as *E. marginata),* and New Caledonia (Risbec, 1953).

Elysia rufescens (Pease, 1871b). Fig. 146 A. Length, 11 mm; parapodial height, 3 mm. *Animal:* parapodia low but erect, with two or three undulations; rhinophores long and slender, directed anteriorly; pericardial prominence a white sac at the anterior end of the parapodia. *Color:* dark red maculated with spots of creamy green which impart a reticulated appearance to the animal; parapodia margined with orange; rhinophores dark red tipped with purple.

Specimens have been collected at various times during the year; the animals are usually found on the sides of rocks in shallow waters shoreward of fringing reefs.

While it is tempting to utilize another Pease name for this species, *E. bella* (Pease, 1860), described from Hawaii, the description of *E. bella* is too vague to assign the name to any recently collected animals with certainty.

Plakobranchus ocellatus van Hasselt, 1824. Fig. 144 F. (Synonyms: *Placobranchus ianthobapsus* Gould, 1852; *Elysia ocellata* Pease, 1860; *Placobranchus argus* Bergh, 1872a.) Length, 40 mm; diameter, 10 mm. *Animal:* elongate, dorsoventrally compressed; oral hood broad with the angles produced as cephalic tentacles rather like the horns of an ox; parapodia flat, meeting middorsally, and with a triangular cardiac protuberance between them; posterior end blunt. *Color:* yellow-green to pale green with ocelli crowding the surface, some yellow or brown with an orange center, others olive-green with a green center, and some green with a sky-blue center; cephalic tentacles yellow-white or green, tipped with purple-red; foot blue-green, with yellow-white or green, tipped with purple-red; interior of folds bright green owing to chloroplasts of the cells of the digestive gland; foot blue-green, with variously colored ocelli; posterior end of foot and anterior margin of oral hood bordered with purple.

These animals are common in sandy, silty areas of bays and the shallow waters shoreward of fringing reefs. They spawn the year round. The egg masses are found on *Halimeda, Acanthophora,* and other algae. The larvae grow from a shell length of 150 μm at hatching to a length of 220 μm in 21 days (Dunlap, 1975). Laboratory-reared larvae do not contain chloroplasts, and Dunlap (1975) suggests they are acquired when metamorphosed juveniles begin feedings.

P. ocellatus is a well-known species throughout the Indo-West Pacific.

Family **Hermaeidae**

(Stiligeridae)

In these sacoglossans the dorsal surface is decorated with two rows of cerata, the inner row larger than the other. The body is elongate, and with the cerata, the animals may easily be mistaken for aeolids; they are distinguished, however, by the form of the rhinophores which are distinctly enrolled. Although at least five species occur in Hawaii, none has been found in sufficient numbers to warrant identification.

Family **Caliphyllidae**

Paddlelike lobes projecting from the dorsum distinguish the members of this family.

Branchophyllum pellucida (Pease, 1860). Fig. 146 G. Length, 25 mm; width, 10 mm. *Animal:* elongate with transparent, paddlelike lobes projecting dorsally and laterally; rhinophores bifid, occasionally slightly tuberculate; with labial palps; anus dorsolateral; foot simple, rounded anteriorly, the corners drawn out as tentacular projections. *Color:* dark green with yellow dorsally, the medial papillae clear and transparent, the lateral lobes with dark green, unicellular algal cells.

These animals are common under rocks and rubble along shorelines of Oahu and Kauai where they are found throughout the year. The papillae are contractile and sticky, and the animal casts them off at the slightest disturbance. Egg masses are common between January and March; they consist of three cylindrical, transparent, gelatinous coils, the mass about 10 mm in diameter, each whorl about 2 mm in diameter.

B. pellucida was described from the Hawaiian Islands.

Cyerce elegans Bergh, 1888a. Fig. 144 B. Length, 30 mm; width, 25 mm. *Animal:* elongate with paddlelike lobes projecting dorsally and laterally; rhinophores bifid; with labial palps; anus dorsal, a tube to the right of the cardiac protuberance; foot divided by a transverse groove. *Color:* body and lobes beige, the lobes outlined in cream; anterior edge of foot with a chocolate brown line on the dorsal surface below the mouth; lobes fairly uniform in color but occasionally peppered with black and with a few dark brown streaks.

These animals resemble the brown alga *Padina,* and the few specimens recorded have been found in beds of *Padina.*

C. elegans was described from the Sulu Sea.

Cyerce nigricans (Pease, 1866). Fig. 144 A. Length, 30 mm; width, 18 mm. *Animal:* elongate with projecting, flattened, almost circular, pustular lobes; rhinophores bifid; labial palps present; anus dorsal, a tubular vent to the right of the anterior end of the cardiac protuberance; foot divided by a deep groove, the anterior third broad, the posterior two-thirds narrower. *Color:* head and body translucent, spotted with opaque white and orange or dark brown; lobes translucent brown margined with a narrow band of orange-yellow, dark brown with white spots proximally on one surface and with white pustules on the other; occasionally also with blue spots.

These animals are uncommon, found under rocks on benches and shoreward of reefs subject to considerable wave action.

This species is somewhat doubtfully referred to *C. nigricans* (Pease); although none of the animals were the velvet black color described by Pease, there is so much color variation among the specimens collected that it would seem that they come closest to that species in general facies.

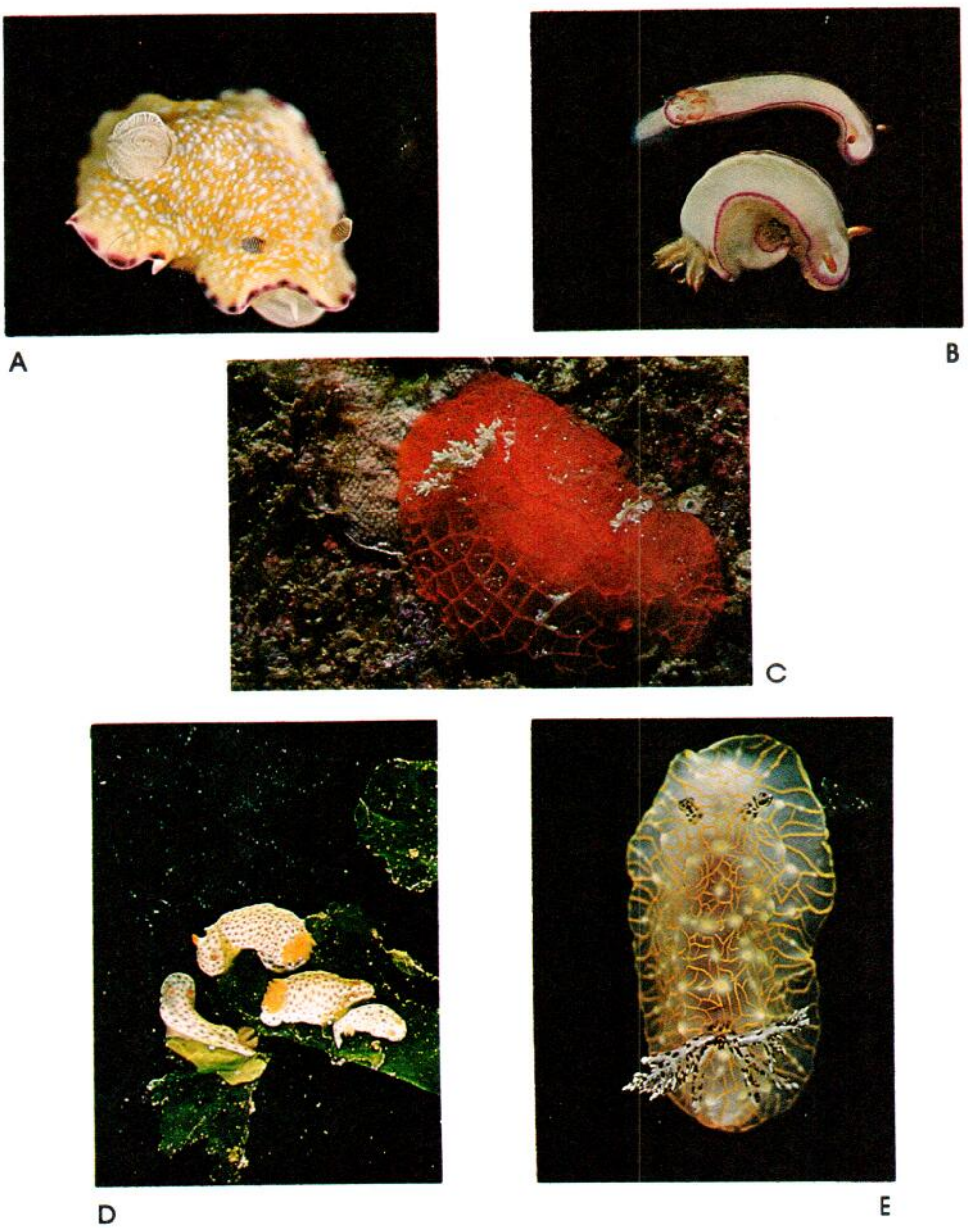


Figure 147.—Some dorids. A. *Chromodoris albopustulosa*, length 21 mm. B. *Hypselodoris daniellae*, length 30 mm. C. *Sclerodoris* sp., length 50 mm. D. *Chromodoris lilacina*, length 9 - 20 mm. E. *Halgerda* sp. cf. *graphica*, length 30 mm. (C. by S. Johnson.)

Order NUDIBRANCHIA

The nudibranchs are distinguished by their bilaterally symmetrical bodies. There is no indication of the spiral tendencies exhibited by most other gastropods except during the larval stage of their life histories. At the anterior end there is a pair of tentacular structures, the rhinophores, clublike, smooth, perfoliate or laminate projections, which are apparently sensory in function. The gills are concentrated at the posterior end (Doridacea), encircle the body under the mantle (Arminacea), or lacking, perhaps replaced by dorsal outgrowths (Dendronotacea and Aeolidacea).

Nudibranchs are found on hard substrates, associated with soft corals and stony corals, and pelagic. In the Doridacea and Dendronotacea there is a tendency toward the development of a swimming habit, some dorids swimming by undulations of the body, the Dendronotacea by movements of the body and cerata. The Phylliroidae (Dendronotacea) and Glaucidae (Aeolidacea) are pelagic, with the cerata produced as elaborate flotation devices.

All nudibranchs for which the feeding habits are known are carnivorous. Some are grazers on sponges (Doridiidae) or coelenterates (Aeolidacea), one *(Okadaia elegans)* bores tube worms, others engulf their prey (Goniodorididae), and *Melibe* (Tethyidae) is a net caster, presumably capturing small crustaceans.

Superfamily DORIDACEA

This group of nudibranchs is composed of animals with broadly oval to elongate bodies and a middorsal anus partially or entirely encircled by secondary branchiae or gills. Most of the Hawaiian dorids are found in shallow water, under and in chunks of dead coral on fringing reefs, usually in areas protected from wave action and sediment deposition but where there is a fair amount of water exchange. There are at least five different feeding types: the dorids and dendrodorids are rasping and sucking sponge feeders; the gymnodorids engulf other opisthobranchs; *Okadaia elegans* bores into polychaete worms; and the goniodorids probably feed on ascidians. Development is direct in *Okadaia elegans,* but other dorids have a pelagic veliger larval stage. The egg masses are in the form of coiled ribbons (Fig. 131 F).

Family **Doridiidae**

This family includes dorids with a large, spreading notum which is usually ornamented with spicules and papillae, and with retractile, laminate rhinophores. These dorids are rasping sponge feeders grazing on sponges on the undersurfaces of rocks.

Most species appear to be specific in their feeding habits, rasping only on particular species of sponges. The egg masses are coiled, flat ribbons which closely adhere to the substrate.

Nine subfamilies are represented in Hawaii, distinguished by differences in radular teeth and genitalia (Young, 1966; Kay and Young, 1969).

Subfamily **Doridinae**

The subfamily includes dorids without jaws, with hamate radular teeth, without a conspicuous prostate, and with a cirrus rather than a penis in the male reproductive tract. Two genera are represented, *Doriopsis* with a semicircular row of gills, and *Doriorbis* with a circular row of gills, about the anus.

Doriopsis granulosa Pease, 1860. Fig. 148 G. Length, to 11 mm; width, to 4 mm. *Animal:* oblong-ovate, convex above, rather rigid; mantle studded with minute, irregular spicular granules. *Color:* variable — pale yellow, buff, occasionally with green spots and/or a blue tinge dorsally; rhinophores, branchiae, and ventral surface of foot pale yellow. *Rhinophores:* short, widely spaced, with eight to ten lamellae. *Branchiae:* eight or nine simply pinnate gills arranged in a semicircle about the anus.

These dorids are common, found under rocks in shallow water on fringing reefs. They feed on the blue sponge, *Terpios zeteki*.

D. granulosa is found throughout the Indo-West Pacific, from Tanzania (Edmunds, 1971) to New South Wales, New Caledonia, New Zealand, Japan, and Tahiti (Kay and Young, 1969).

Doriopsis pecten (Collingwood, 1881). Fig. 131 F. Length, to 16 mm; width, to 7 mm. *Animal:* oblong-ovate, convex above, rather rigid; mantle with minutely granular and spicular papillae. *Color:* mantle, rhinophores and branchiae dark blue, foot pale blue. *Rhinophores:* elongate, finely lamellate. *Branchiae:* seven or eight simply pinnate gills arranged in a semicircle about the anus.

A commonly occurring species like *D. granulosa,* these animals occur in a similar habitat but feed on a blue sponge *(Terpios aploos)* against which they are almost invisible. The egg masses are pale yellow.

D. pecten was described from Taiwan and also occurs in the Marshall Islands, Japan, New Caledonia, and New South Wales, Australia (Kay and Young, 1969).

Doriorbis nucleola (Pease, 1860). Fig. 148 A. (Synonyms: *Doris papillosa* Pease, 1860; *D. papillata* "Pease," Abraham, 1877; *D. tincta* Pease, 1864.) Length, to 15 mm; width, to 6 mm. *Animal:* ovate, convex, rigid and scaly to the touch; mantle with a sparse scattering of small, irregular papillae and spicules. *Color:* variable — brown or gray-blue, with a T- or Y-shaped yellow streak extending from the rhinophores to the middorsum; rhinophores and branchiae brown. *Rhinophores:* small, set far apart, finely lamellate. *Branchiae:* five to six pinnate to feathery gills encircling the anus.

These dorids are fairly common, found under rocks in shallow waters shoreward of fringing reefs.

This species was described from the Hawaiian Islands.

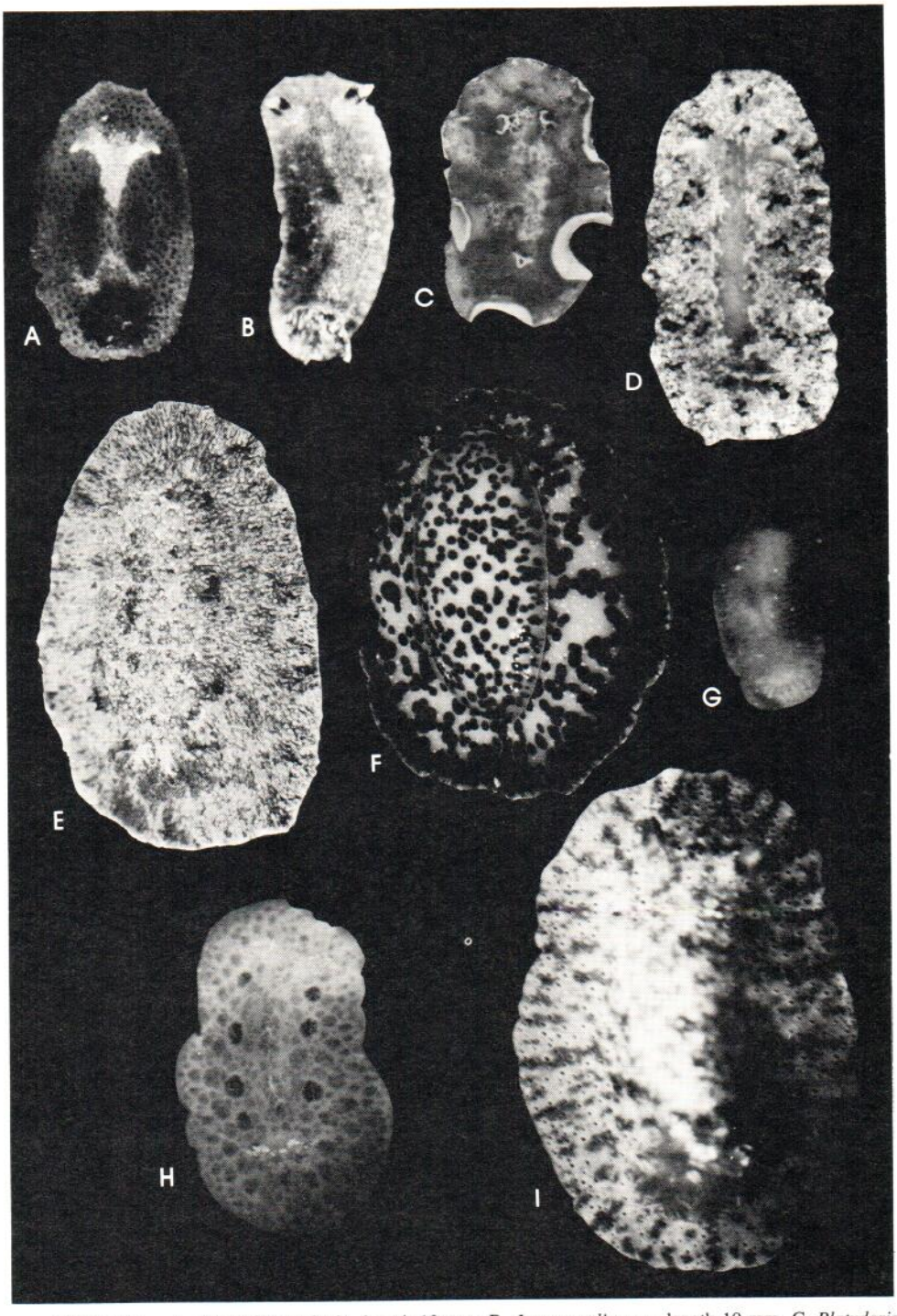


Figure 148.—A. *Doriorbis nucleola*, length 13 mm. B. *Jorunna alisonae*, length 10 mm. C. *Platydoris formosa*, length 65 mm. D. *Carminodoris nodulosa*, length 33 mm. E, F. *Archidoris nubilosa*, length 110 mm. G. *Doriopsis granulosa*, length 10 mm. H. *Discodoris fragilis*, length 32 mm. I. *Archidoris hawaiiensis*, length 110 mm.

Subfamily **Archidoridinae**

Members of this subfamily are rather soft in consistency, and the dorsal surface is either studded with small, round papillae or set with numerous tentacular processes. The radula has numerous hook-shaped plates and the jaw is unarmed. There is a large, free ventricle in the reproductive system, and the penis and vagina are unarmed.

Archidoris hawaiiensis Kay and Young, 1969. Fig. 148 I. Length, 110 mm; width, 50 mm. *Animal:* ovate, wider toward the middle than anteriorly or posteriorly, crisp to the touch; mantle studded with small round papillae. *Color:* red-brown with patches of darker and minute white spots ocellated with black; rhinophores red-brown with white tips; branchiae transparent brown; foot white mottled with purple-brown. *Rhinophores:* elongate, with nine or ten fine lamellae which are retractile into smooth sheaths. *Branchiae:* five feathery structures surrounding the anus.

These dorids are uncommon, recorded from shallow water in Kaneohe Bay, Oahu, and near Koloa, Kauai.

A. hawaiiensis was described from the Hawaiian Islands.

Archidoris nubilosa (Pease, 1871c). Fig. 148 E, F. Length, to 200 mm; width, to 160 mm. *Animal:* broadly oval, soft and flaccid, with thin, undulating margins; mantle ornamented with closely set, soft papillae and tentacular processes of unequal size. *Color:* mantle mottled with brown and gray; rhinophores gray-brown with white tips; branchiae light brown veined with darker on a white rachis; foot white with purple-red spots and a purple margin. *Rhinophores:* clublike. *Branchiae:* six feathery gills.

A few specimens have been recorded in shallow water in September, October, February, and March. The animals secrete great quantities of mucus when disturbed, and large portions of the mantle may be cast off. The mantle margins are extremely flexible, and *A. nubilosa* swims as does *Hexabranchus*.

A. nubilosa was described from Tahiti (Pease, 1871c); it has also been recorded from Zanzibar (as *Thordisa crosslandi* Eliot, 1903).

Subfamily **Platydoridinae**

These dorids have hard, minutely granular mantles, and there are large, disklike hooks in the ejaculatory duct.

Platydoris formosa (Alder and Hancock, 1866). Fig. 148 C. Length, to 76 mm; width, to 50 mm. *Animal:* broadly ovate, mantle rigid and granular to the touch and thin and irregular about the foot. *Color:* white or cream, finely peppered with brown or black and with patches of orange; rhinophores orange with white peduncles; branchiae transparent white or cream, veined with brown; foot white freckled with brown or black. *Rhinophores:* clublike, retractile into scalloped sheaths. *Branchiae:* feathery; sheath scalloped.

These dorids have been collected on the reef platform at Ala Moana, Oahu, in December and January.

P. formosa has been recorded from a number of localities in the Indo-West Pacific.

Subfamily **Kentrodoridinae**

Members of this subfamily have either a smooth or a minutely spiculate mantle. The radular teeth are simply hamate and there are no jaws in the buccal mass. There is a lateral stylet in the genital mass and the ejaculatory duct is unarmed.

Jorunna alisonae Marcus, 1976. Fig. 148 B. (Synonym: *Jorunna tomentosa* (Cuvier, 1804a), Kay and Young, 1969.) Length, to 12 mm; width, to 6 mm. *Animal:* elongate-oval, convex, soft, mantle margins only slightly irregular about the foot; mantle covered by a thick covering of minute, spiculate papillae. *Color:* pale gray to drab with spots of brown or gray in parallel rows dorsally; rhinophores gray to brown; branchiae dusky gray to brown; foot white. *Rhinophores:* short, close-set, thick, with seven to nine oblique lamellae and a tubular tip; sheaths papillate. *Branchiae:* five to eleven branched, bi- or tripinnate gills forming a posteriorly directed basketlike structure.

These dorids are common, found under rocks in shallow water shoreward of fringing reefs. They feed on the sponge *Haliclona permollis*.

Marcus (1976) distinguishes the Hawaiian animals (and those reported by Young, 1967, from the Marshall Islands) from the European *J. tomentosa* on the basis of the presence of labial rodlets and longer vestibular stylet.

Asteronotus cespitosus (van Hasselt, 1824). Fig. 149 F. Length, to 130 mm; width, to 50 mm. *Animal:* broadly ovate, depressed, soft and leathery in consistency; mantle with an anteroposteriorly oriented, irregularly pustulose, median ridge, and with smaller ridges and protuberances laterally. *Color:* mantle gray-brown or yellow; rhinophores pale gray on translucent peduncles; foot yellow-white. *Rhinophores:* large, perfoliate; sheaths plain and tubular. *Branchiae:* feathery; branchial sheath divided into six lobes.

The few specimens recorded were found in shallow water on the reef platform at Ala Moana, Oahu, or at depths of about 2 m.

A. cespitosus is widely distributed in the Indo-West Pacific, recorded from the Philippines to the Ryukyu Islands and Zanzibar (as *A. hemprichii* Ehrenberg, Eliot, 1903).

Subfamily **Discodoridinae**

The discodorids have minutely granulate or pustulose mantles which have the tendency to fragment when the animal is disturbed. The jaws are set with rods which are in the form of transverse, ringlike growths.

Carminodoris grandiflora (Pease, 1860). (Not figured.) Length, 38 mm; width, 25 mm (preserved). *Animal:* oblong-oval, rigid, convex above; mantle ornamented with large, somewhat irregular pustules. *Color:* mantle fawn reticulated with paler coloration and splashes of brown; rhinophores fawn; branchiae dusky fawn. *Rhinophores:* stout, close-set, peduncle equal in length to the lamellar portion; sheath tubular. *Branchiae:* five feathery, procumbent gills.

Specimens are recorded from reefs in Kaneohe Bay, Oahu.

C. grandiflora was described from the Hawaiian Islands.

Carminodoris nodulosa (Angas, 1864). Fig. 148 D. Length, to 35 mm; width, to 24 mm. *Animal:* oval, crisp and rigid, dorsum convex; mantle studded with small pustules which become more numerous toward the edge and with a smooth central longitudinal streak. *Color:* mantle light brown splashed with darker and with a central, anteroposteriorly directed band of red-brown; rhinophores brown; branchiae cream with flecks of brown. *Rhinophores:* large, perfoliate; retractile into scalloped sheaths. *Branchiae:* feathery; sheath scalloped.

This is a shallow-water species, found on the reef platform at Ala Moana, Oahu, and on the wave-swept bench at Diamond Head, Oahu.

C. nodulosa was described from Port Jackson, New South Wales, and has been recorded from northern New South Wales to central Victoria in Australia (Burn, 1965).

Discodoris fragilis (Alder and Hancock, 1866). Fig. 148 H. Length, to 35 mm; width, to 20 mm. *Animal:* broadly oval, crisp and rigid, barely convex above; mantle margins thin, undulated; mantle ornamented with a dense mat of slender, short, upstanding clusters of spicules. *Color:* mantle gray, mottled with light and dark, often with patches of dark pigment laterally; rhinophores dusky; tipped with cream; branchiae dusky; ventral surface of mantle and foot cream with dark speckles.

D. fragilis is one of the commonest of the Hawaiian dorids, frequently collected under coral rubble and rocks on benches, reef platforms, and shoreward of fringing reefs. Portions of the mantle are often shed when the animals are disturbed.

This species is found from the Red Sea and India to the Philippines and Samoa.

Subfamily **Trippinae**

These dorids have mantles ornamented with compound tubercles and ridged reticulations, or their mantles are spiculate or papillate. The radular teeth are simply hamate and there are neither jaws nor buccal armature.

Trippa echinata (Pease, 1860). Fig. 149 A. Length, to 24 mm; width, to 8 mm. *Animal:* elongate-oval, dorsum convex; mantle studded with small, globular, spinose granules. *Color:* mantle cream white with brown spots; rhinophores and branchiae dusky; foot white. *Rhinophores:* close-set, stoutly pedunculate, mucronate. *Branchiae:* tripinnate; sheath with stellate ornamentation.

This is a commonly occurring dorid, found under rocks on the reef platform at Ala Moana, Oahu, and in the shallow waters shoreward of fringing reefs at Nanakuli, Oahu, and near Koloa, Kauai.

T. echinata was described from the Hawaiian Islands.

Trippa osseosa (Kelaart, 1859). Fig. 149 B. (Synonyms: *Doris excavata* Pease, 1860, non *excavata* Stimpson, 1855; *D. oreosoma* Pease, 1864.) Length, 28 mm; width, 14 mm. *Animal:* elongate-oval, convex; mantle sculptured by a middorsal, anteroposteriorly directed ridge from which branch lateral ridges enclosing rather deep pits. *Color:* white or dirty gray; rhinophores brown. *Rhinophores:* close-set, long and

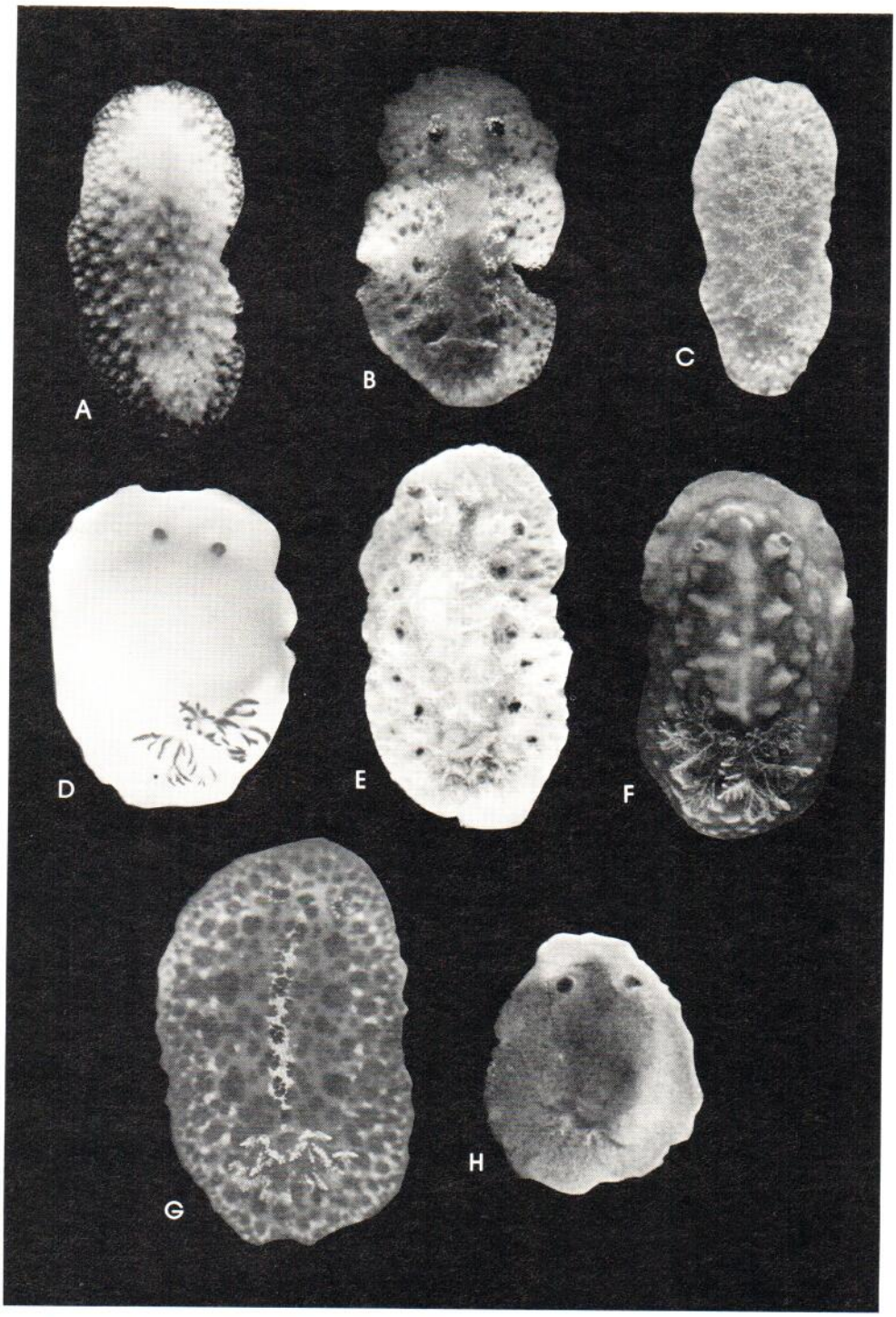


Figure 149.—A. *Trippa echinata*, length 16 mm. B. *T. osseosa*, length 24 mm. C. *T. scabriuscula*, length 19 mm. D. *Peltodoris fellowsi*, length 40 mm. E. *Sclerodoris*, sp., length 29 mm. F. *Asteronotus cespitosus*, length 100 mm. G. *Thordisa setosa*, length 30 mm. H. *T. hilaris*, length 14 mm.

slender; sheaths crenulate. *Branchiae:* six tripinnate gills; branchial cavity crenulate and thrown into six prominent folds.

The only specimen found in recent years came from the wave-swept bench at Diamond Head, Oahu.

T. osseosa was described from Ceylon (Kelaart, 1859).

Trippa scabriuscula (Pease, 1860). Fig. 149 C. Length, to 20 mm; width, to 10 mm. *Animal:* elongate-oval, wider posteriorly than anteriorly; scaly and somewhat rigid to the touch; mantle sculptured by reticulate ridges and pits with pustulate tubercles where the ridges meet and with the pits especially prominent along the midline. *Color:* mantle gray or olive-green, pustules creamy white and pits dark gray; rhinophores gray-green; branchiae dark gray; foot white or cream. *Rhinophores:* long and slender, without peduncles and with 18 to 20 lamellae emerging from a pustulate sheath. *Branchiae:* five- or six-branched, simply pinnate gills; sheath smooth.

These dorids are uncommon, found on the reef platform at Ala Moana, Oahu, and on a limestone bench and in shallow water shoreward of a fringing reef near Koloa, Kauai.

This species was described from the Hawaiian Islands.

Subfamily **Halgerdinae**

In these dorids the mantle is ridged or reticulate with depressions between the raised features. The radular teeth are hamate and either smooth or denticulate; there are neither jaws nor armature.

Halgerda sp. cf. *graphica* Basedow and Hedley, 1905. Fig. 147 E. Length, to 30 mm; width, to 22 mm. *Animal:* oval, smooth and gelatinous to the touch, dorsum convex, margins of mantle thin; mantle ornamented with maplike ridges forming quadrilateral figures with pustules at their junctions and with a middorsal series of pustules forming an indication of a medial ridge. *Color:* mantle transparent, gelatinous white with orange lines marking the dorsum and yellow and white tubercles; rhinophores and branchiae white spotted with brown-black; foot white, margined with orange-yellow. *Rhinophores:* long and slender, close-set. *Branchiae:* two branchial rachiae, each with four branches.

This species occurs at depths of from 1.5 m to 14 m.

Although the Hawaiian animals resemble the species described by Basedow and Hedley from Western Australia, they differ in that they lack the dark central spots occurring in the center of the reticulations, the brown rhinophores and black branchiae.

Sclerodoris sp. Fig. 149 E. (Synonym: *Halgerda* sp. cf. *apiculata* (Alder and Hancock, 1866), Kay and Young 1969.) Length, to 70 mm; width, to 30 mm. *Animal:* oblong-ovate, ridged and scabrous, convexly rounded above; mantle ornamented with ridges and grooves, the ridges forming small tubercles where they meet. *Color:* yellow-gray with brown-gray ridges and darkly pigmented lateral depressions; rhinophores with yellow peduncles and brown lamellae; branchiae dusky; foot yellow.

Rhinophores: oblong-ovate; sheaths scalloped. *Branchiae:* six or seven feathery gills; sheath scalloped.

Specimens have been collected on the reef platform at Ala Moana, Oahu.

Rudman (1978), reviewing the species of *Halgerda* and *Sclerodoris* notes that the Hawaiian dorids identified as *Halgerda* sp. cf. *apiculata* (Alder and Hancock, 1866) by Kay and Young (1969) differ from animals of that species in having denticles on the radular teeth and in not having fleshy papillae on the mantle.

Sclerodoris sp. Fig. 147 C. (Synonym: *Halgerda rubra* (Bergh, 1905) Kay and Young, 1969.) Length, to 88 mm; width, to 40 mm. *Animal:* oval, smooth and rigid to the touch, dorsum convex, mantle margins thin and irregular; mantle ornamented with raised reticulations which give the animal the appearance of a piece of sponge. *Color:* mantle orange or orange-red with irregular white and/or vermilion spots and with black pigmentation in the concavities; rhinophores orange-red to orange-brown with white tips; branchiae orange-red or orange-brown; foot and ventral surface of mantle orange-red. *Rhinophores:* fusiform; sheath with a jagged edge. *Branchiae:* five to eight tripinnate gills.

This dorid is usually found at depths of 50 to 60 m; a single animal was collected at a depth of 0.5 m when it was spawning.

Rudman (1978) reviewing *Halgerda* and *Sclerodoris*, notes that the Hawaiian dorids identified by Kay and Young (1969) as *Halgerda rubra* (Bergh, 1905), do not represent that species and considers them an unnamed new species of the genus.

Subfamily **Diaululinae**

This subfamily includes dorids with a firm, more or less depressed body, minutely villous and often velvety mantle, and with a round, crenulate branchial aperture. There is no labial armature, the radula lacks a central tooth and the laterals are hamate and numerous; the penis is unarmed.

Thordisa hilaris Bergh, 1905. Fig. 149 H. Length, to 12 mm; width, to 7 mm. *Animal:* broadly oval, somewhat depressed, rigid and like sandpaper to the touch; mantle with minute, transparent papillae. *Color:* orange, microscopically peppered with black; rhinophores brown tipped with a white nipple; branchiae orange microscopically peppered with black; foot orange. *Rhinophores:* thick with circular, crenulate sheaths. *Branchiae:* six tripinnate gills which spread starlike across the posterior of the mantle.

These animals are associated with an orange sponge which they resemble in color, and the egg mass is also orange.

T. hilaris was described from the Sulu Sea.

Thordisa setosa (Pease, 1860). Fig. 149 G. (Synonym: *Doris pilosa* Pease, 1860.) Length, to 55 mm; width, to 20 mm. *Animal:* broadly oval, depressed, narrower anteriorly than posteriorly, fairly soft to the touch; mantle ornamented with a dense felting of small, rounded papillae between which project longer tentacular processes. *Color:* mantle purple-red or gray with patches of darker pigment; rhinophores ashy

gray. *Rhinophores:* close-set, short, lamellated but without a peduncle. *Branchiae:* ten moderately feathery gills; branchial sheath barely papillate.

These dorids are rather common, found in shallow waters shoreward of fringing reefs where they cling to the undersurfaces of rocks, often taking the shape of the substrate.

This species was described from the Hawaiian Islands; Eliot's (1900) record of an animal as *Doris setosa* from Samoa differs in several respects from Hawaiian dorids.

Peltodoris fellowsi Kay and Young, 1969. Fig. 149 D. Length, 40 mm; width, 20 mm. *Animal:* oval, depressed; mantle rigid, ornamented with numerous fine granules. *Color:* mantle white; rhinophores with jet black lamellae, rachis of branchiae red-brown, pinnae jet black. *Rhinophores:* rodlike; sheaths with smooth margins. *Branchiae:* tripinnate with six branches from two main rachids.

This species occurs in moderately deep water at depths of 10 m.

P. fellowsi was described from the Hawaiian Islands.

Subfamily **Chromodoridinae**

The chromodorids comprise a rather compact group of elongate, smooth and slimy, brilliantly colored dorids which are well represented within the Indo-West Pacific. Three genera are found in Hawaiian waters: *Ceratosoma,* with a peculiar high body and a mantle brim; and *Chromodoris* and *Hypselodoris,* with elongate, compressed bodies. In *Chromodoris* the radular teeth are unicuspidate; in *Hypselodoris* they are bicuspidate. The members of the subfamily are distinguished from other dorids by the hook-shaped buccal armature set in a horseshoe-shaped jaw, and the lack of a spermathecal duct.

Ceratosoma cornigerum Adams and Reeve, 1848. (Not figured.) Length, 34 mm; width, 7 mm. *Animal:* limaciform, rather hard in consistency, the branchiae higher than the head and rhinophores and the head with a rounded frontal veil; mantle three-lobed posteriorly and the foot prolonged into a tail nearly the same length as the body. *Color:* orange-red with a few purple spots variously distributed and areas of white with smaller purple spots beneath the mantle brim; rhinophores yellow; branchiae orange-red; foot white, spotted with purple at the base. *Rhinophores and branchiae:* retractile into smooth, swollen sheaths.

Only a few animals have been collected, one at a depth of 0.5 m off Barbers Point, Oahu, two or three others at depths of 8 to 10 m.

C. cornigerum is apparently a common shallow-water species elsewhere in the Indo-West Pacific, where it has been recorded from the Red Sea and Indian Ocean, New South Wales, Japan, the Philippines, and Indonesia (Kay and Young, 1969).

Chromodoris albopustulosa (Pease, 1860). Fig. 147 A. Length, to 25 mm; width, to 7 mm. *Animal:* oval-oblong, rather wide, soft; mantle margin tending to cover the foot in irregular folds; mantle ornamented with depressed pustules. *Color:* mantle lemon yellow, pustules white, margin edged with purple either as a continuous band or

in spots; rhinophores orange to orange-brown, laminae edged in white; branchiae transparent white. *Rhinophores:* large and well spaced with six to eight lamellae. *Branchiae:* six to eleven feathery gills forming a basketlike structure.

These dorids occur under rocks in shallow water shoreward of fringing reefs.

C. albopustulosa was described from the Hawaiian Islands and has been recorded from "the Pacific" (Bergh, 1888a) and Enewetak, Marshall Islands (Young, 1967).

Chromodoris decora (Pease, 1860). Fig. 150 A. Length, to 20 mm; width, to 5 mm. *Animal:* oval, broad, somewhat depressed. *Color:* mantle ivory with a median flake-white stripe running posteriorly from the rhinophores to the middorsum where it bifurcates and borders the branchiae, the white stripe and margins dotted with purple and the mantle margin bordered by a broad orange band dotted with purple; rhinophores and branchiae white.

C. decora is a rather commonly occurring species, found under rocks on the reef platform at Ala Moana, Oahu, and in shallow waters shoreward of fringing reefs.

This species was described from the Hawaiian Islands and has been recorded from Japan (Baba, 1953) and New South Wales (Allan, 1947).

Chromodoris imperialis (Pease, 1860). Fig. 150 H. Length, 65 mm; width, 25 mm. *Animal:* elongate-oval, soft, depressed; mantle margin thin, fluted. *Color:* mantle rich orange-yellow ocellated with white, margin lemon-yellow edged with brilliant purple; rhinophores purple spotted with darker and striped with white at the apex; branchiae pale purple with the rachis striped with white. *Rhinophores:* widely spaced, broad, with deep lamellae. *Branchiae:* seven doubly pinnate gills arranged in star-shaped fashion around the anal papilla.

These dorids are found at depths of about 10 m at the edge of the reef platform at Ala Moana, Oahu.

C. imperialis was described from the Hawaiian Islands.

Chromodoris lilacina (Gould, 1852). Fig. 147 D. Length, to 30 mm; width, to 7 mm. *Animal:* oval, convex, soft; mantle margin labile and fluting around the foot, often frilled in the head region. *Color:* mantle cream ornamented with bright purple spots which also appear on the foot; rhinophores and branchiae orange-yellow or straw-colored. *Rhinophores:* widely spaced, slender, with ten to twelve lamellae. *Branchiae:* six to eight simply pinnate gills.

This is the most commonly occurring of the Hawaiian chromodorids, found under rocks exposed at low tide on reef platforms and in shallow waters shoreward of fringing reefs.

C. lilacina was described from the Hawaiian Islands and has been recorded from Ceylon (as *Doris amabilis* Kelaart, 1859) and Mauritius (as *Chromodoris porcata* Bergh, 1888a) (Young, 1967).

Chromodoris marginata Pease, 1860. Fig. 150 D. (Synonym: *Chromodoris trimarginata* Winckworth, 1946, Kay and Young, 1969.) Length, to 11 mm; width, to 4 mm. *Animal:* elongate, convexly rounded above, often somewhat constricted me-

dially and wider posteriorly. *Color:* mantle white, edged with a brilliant yellow and orange margin; branchiae, rhinophores and foot white. *Rhinophores:* small, close-set, short, of about 12 lamellae. *Branchiae:* six simply pinnate gills.

These dorids are found under rocks in shallow water shoreward of fringing reefs.

C. marginata was described from the Hawaiian Islands. Thompson (1972) recognizes it as distinct from *C. trimarginata* Winckworth, 1946, from Bombay, distinguished by the red margin (in *C. trimarginata* the margin is orange) and records *C. marginata* from New South Wales, Australia.

Chromodoris petechialis (Gould, 1852). Fig. 150 B. (Synonym: *Doris reticulata* Pease, 1860.) Length, to 40 mm; width, to 15 mm. *Animal:* oval, depressed, broadening toward the middle of the body; mantle margin thin, fluted. *Color:* mantle white reticulated with purple-red, the reticulations forming blotches toward the margin, which is edged with golden yellow; rhinophores yellow-orange to orange-red with a white peduncle; branchiae white, the pinnae edged with light brown or purple. *Rhinophores:* close-set, long, with twenty fine lamellae. *Branchiae:* simply pinnate, arranged in starlike fashion around the anal papilla.

This species occurs at depths of from 8 to 20 m.

C. petechialis was described from the Hawaiian Islands and has been recorded from the Inland Sea of Japan and Karachi (Eliot, 1905b). Rudman (1973) questions the identification of the Hawaiian animals by Kay and Young (1969) as *C. petechialis,* and suggests that Eliot's specimens would seem more likely to be *C. inornata* Pease, 1871c, from Tahiti.

Chromodoris youngbleuthi Kay and Young, 1969. Fig. 150 C. Length, to 21 mm; width, to 9 mm. *Animal:* elongate, slender, convex, the mantle and viscera maintained discretely above the foot. *Color:* mantle white, minutely freckled with orange-red and margined with white and orange-yellow; rhinophores dark orange with a white apex; branchiae orange-red tipped with light yellow. *Rhinophores:* close-set, slender, elongate, with narrow lamellae. *Branchiae:* seven to ten simply pinnate, vibrating gills in a star-shaped arrangement around the anal papilla.

This species occurs in moderately deep water, at depths of 12 m.

C. youngbleuthi was described from the Hawaiian Islands and also occurs on the Great Barrier Reef (as *Glossodoris marginata* (Gillett and McNeill, 1959)), and in Fiji (Rudman, 1973).

Hypselodoris daniellae Kay and Young, 1969. Fig. 147 B. Length, to 30 mm; width, to 4 mm. *Animal:* elongate, slender. *Color:* mantle snow-white, margined with a brilliant purple band and edged with white; rhinophores white and orange; branchiae white banded with orange on the rachis and occasionally splashed with orange on the pinnae; foot white, the dorsal surface with a light purple line; cephalic tentacles tinted with purple. *Rhinophores:* long, slender, well-spaced. *Branchiae:* simply pinnate and continually vibrating in the living animal.

This is a shallow-water species, found on the reef platform at Ala Moana, Oahu.

H. daniellae was described from the Hawaiian Islands.

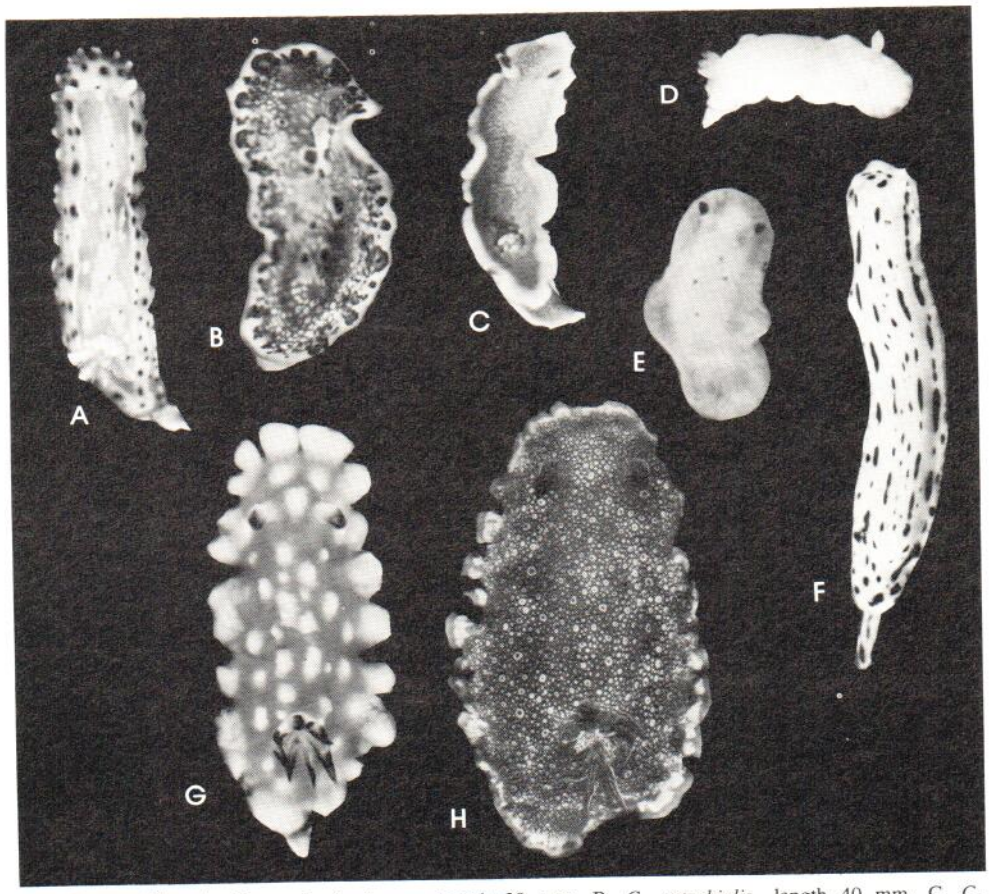


Figure 150.—A. *Chromodoris decora*, length 20 mm. B. *C. petechialis*, length 40 mm. C. *C. youngbleuthi*, length 21 mm. D. *C. marginata*, length 8 mm. E. *Hypselodoris peasei*, length 4 mm. F. *H. lineata*, length 32 mm. G. *H. vibrata*, length 20 mm. H. *Chromodoris imperialis*, length 65 mm.

Hypselodoris lineata (Eydoux and Souleyet, 1852). Fig. 150 F. (Synonyms: *Doris prismatica* var. *lineata* Pease, 1860; *Doriprismatica lineata* Pease, 1864, non *Chromodoris lineolata* (van Hasselt, 1824), Thompson, 1972.) Length, to 32 mm; width, to 4 mm. *Animal:* elongate, slender, convex dorsally; mantle smooth. *Color:* mantle cream or ivory ornamented with four to six longitudinal rows of blue spots, two medially and two to four laterally, the interspaces between the rows with linear splashes of opaque white; margin edged with white, blue, or orange-yellow; rhinophores with a white peduncle and orange lamellae; branchiae transparent white with splashes of orange at the tips. *Rhinophores:* slender, tapering, set far apart. *Branchiae:* nine to twelve, erect, simply pinnate gills.

These dorids are fairly common in shallow water, found in sheltered, shallow waters shoreward of fringing reefs where they are usually seen crawling freely about on the surface of algal-covered rocks. The egg masses are cream-colored.

H. lineata was described from the Hawaiian Islands, and is thought to be endemic (Rudman, 1977), the records of the species from Africa (Eliot, 1904b; 1905b; Barnard, 1927) notwithstanding.

Hypselodoris peasei (Bergh, 1880a). Fig. 150 E. (Synonyms: *Doris picta* Pease, 1860, non *picta* Schultz, 1836 or Kelaart, 1858.) Length, to 18 mm; width, to 4.5 mm. *Animal:* oval, flattened, often bulging laterally in the midregion; mantle smooth. *Color:* mantle opaque white, inconspicuously and irregularly spotted with orange-yellow and margined with a thin band which varies from carmine to orange-red from specimen to specimen and even in the same animal; rhinophores white, apically tipped with orange; branchiae white, occasionally splashed with orange. *Rhinophores:* well-spaced, short, with four or five lamellae and a long peduncle. *Branchiae:* six, small simply pinnate gills.

This is a common shallow-water species, found along a variety of shorelines, always under rocks and usually firmly lodged in crevices.

This species was described from the Hawaiian Islands.

Hypselodoris vibrata (Pease, 1860). Fig. 150 G. (Synonym: *Chromodoris propinquata* Pease, 1860.) Length, to 35 mm; width, to 14 mm. *Animal:* elongate-oval, depressed, the mantle margin fluting about the foot; mantle smooth, occasionally with pustules. *Color:* mantle yellow, pustules white, the margin edged with purple which forms linear indentations anteriorly and posteriorly and spots laterally; rhinophores white or brown, tipped with purple; branchiae white tipped with purple. *Rhinophores:* widely spaced, thin, elongate with 11 to 25 lamellae. *Branchiae:* eight to ten simply pinnate, upstanding, vibratile gills.

Most specimens recorded have been found in shallow water, but a single animal was collected at a depth of 6 m in Kaneohe Bay.

H. vibrata was described from the Hawaiian Islands.

Family **Hexabranchidae**

These dorids are large (often more than 100 mm in length), soft-bodied, and conspicuously colored red and yellow. The mantle is smooth, and the margins thin and undulated; the animals are often active, swimming by mantle undulation as well as crawling. The hexabranchids are rasping sponge feeders.

Hexabranchus aureomarginatus Ostergaard, 1955. Fig. 151 G. Length, to 80 mm; width, to 35 mm. *Animal:* elongate-oval, soft, convex above. *Color:* mantle red, mottled with a few large, peppered white spots and margined with yellow; rhinophores orange-red with yellow peduncles; branchiae yellow, veined with red. *Rhinophores:* posteriorly oriented. *Branchiae:* two separate rachi with additional branches, contractile into a hollow.

These animals are most commonly collected in January, February, and April, but occasional specimens are also found in other months of the year; they are usually seen exposed on seaweed in areas shoreward of fringing reefs. A small, bright red shrimp, *Periclimenes imperator* Bruce, 1967, is sometimes found commensal in the gills of this nudibranch.

H. aureomarginatus was described from the Hawaiian Islands.

Hexabranchus sanguineus (Ruppell and Leuckart, 1831). Fig. 151 H. (Synonyms: *Doris sandwichensis* Eydoux and Souleyet, 1852; *Doris cardinalis* Gould, 1852; *Hexabranchus tinkeri* Ostergaard, 1955; *H. marginatus* (Quoy and Gaimard, 1832), Kay and Young, 1969.) Length, to 100 mm; width, to 75 mm. *Animal:* elongate-oval; soft, convex above. *Color:* mantle basically red, middorsum mottled with yellow and white, margins banded with a wide zone of bright red and narrowly edged with a lighter color or white; rhinophores red, sheaths lined with white; branchiae yellow-white with red veining. *Rhinophores:* elongate, tilted posteriorly. *Branchiae:* large, recumbent, on two branched rachi.

These dorids are common in January and February, but occasional specimens are found in other months. They are usually found in areas where there is considerable water movement. They feed on the calcareous sponge *Leucetta solida*. The egg masses consist of bright red, fluted and coiled ribbons. The animals are powerful swimmers, progressing horizontally and upward by a series of graceful jerks and they may swim continuously for several hours. On the substrate they normally lie or crawl with the margins rolled up and in. The mottled color of the dorsal surface makes them difficult to see, but when they are disturbed the mantle margin suddenly unfolds and expands laterally, exposing the brilliant red and white markings of the dorsal surface. Edmunds (1971) suggests exposure of the mantle in this fashion may be a defensive mechanism.

H. sanguineus is one of the commonest and most conspicuous dorids in the Indo-West Pacific, recorded from Tanzania (Edmunds and Thompson, 1972) to New South Wales, and Japan.

Additional Records

Animals representing either a third species, possibly *Hexabranchus pulchellus* Pease, 1860, or juveniles of one of the above species, are occasionally collected in tide pools. They are smaller than the others (33 mm in length, 28 mm in width), golden orange spotted with red, and the mantle margin is white.

Family **Actinocyclidae**

This family is distinguished from other dorid groups by its lateral jaws with small fanglike buccal armature; noncleft odontophore with a long, narrow radula; unicuspid radular teeth with terminal denticles; and a long straight esophagus with a swollen valvule.

Actinocyclus japonicus (Eliot, 1913). Fig 151 D. Length, 60 mm; width, 45 mm. *Animal:* oval, wider posteriorly than anteriorly, soft and leathery; mantle decorated with pustules which are more prominent toward the edges than middorsally. *Color:* mantle brown with darker brown pustules on lighter colored bases; rhinophores brown with minute white spots; branchiae brown; foot and ventral surface of mantle light gray. *Rhinophores:* large, close-set. *Branchiae:* eight feathery gills projecting posteriorly as a closed basket.

A single specimen has been recorded, found exposed on a reef in Kaneohe Bay in July, 1963. The spawn consists of a white, coiled ribbon.

A. japonicus was described from Japan and has also been reported from Vietnam as *Aldisa nhatrangensis* (Risbec, 1956).

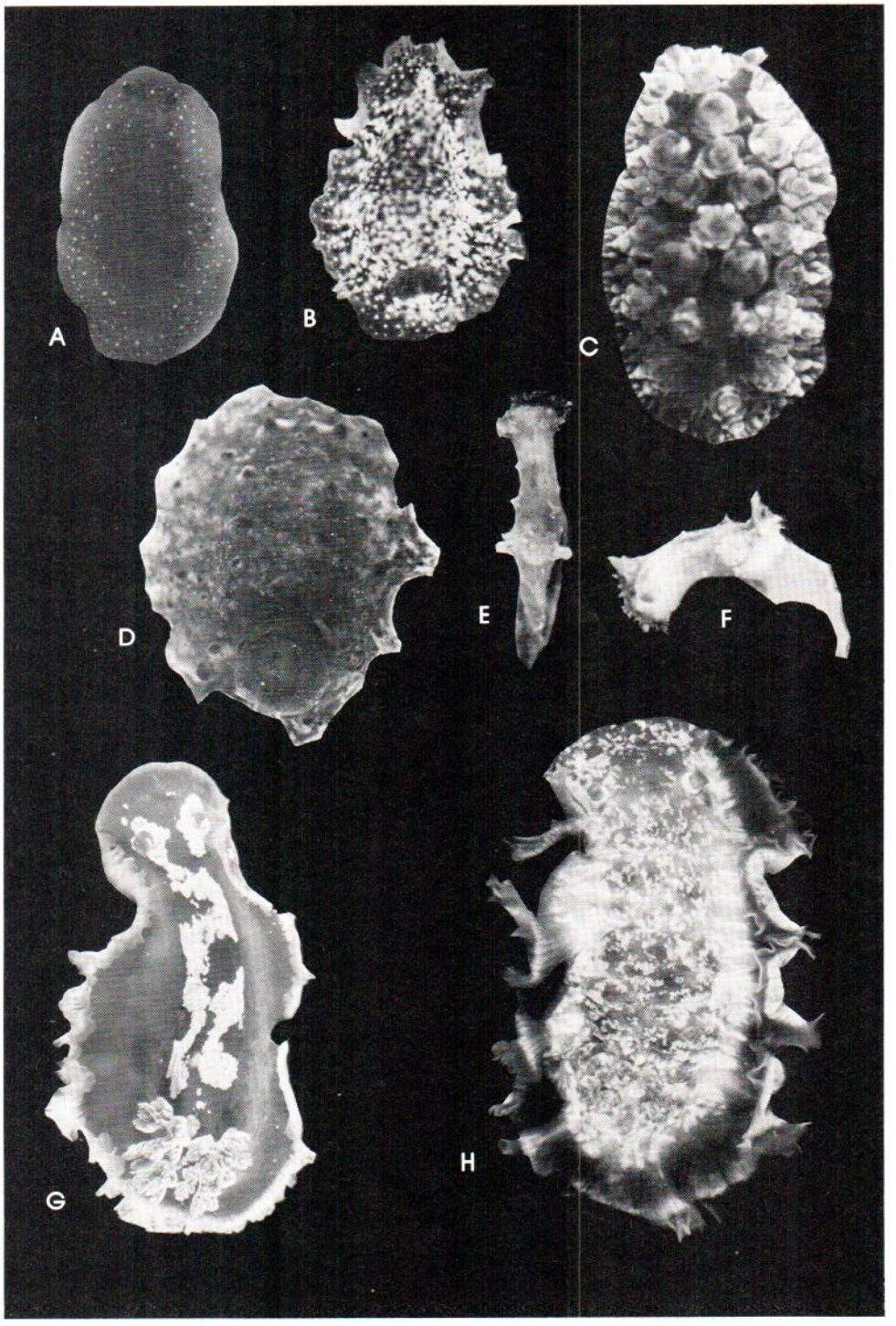


Figure 151.—A. *Dendrodoris nigra*, length 27 mm. B. *D. coronata*, length 24 mm. C. *D. tuberculosa*, length 100 mm. D. *Actinocyclus japonicus*, length 60 mm. E, F. *Plocamopherus maculatus*, length 18 mm. G. *Hexabranchus aureomarginatus*, length 75 mm. H. *H. sanguineus*, length 80 mm.

Family **Dendrodorididae**

The Dendrodorididae include oval, soft-bodied animals which are either smooth or covered with soft warts or blisterlike pustules. The dendrodorids are sponge-feeders, but lack a radula and feed by means of a suctorial buccal apparatus.

Dendrodoris coronata Kay and Young, 1969. Fig. 151 B. Length, to 30 mm; width, to 17 mm. *Animal:* broadly oval, wider posteriorly than anteriorly, soft, convex above, the mantle margin thin and undulated; mantle ornamented with numerous irregularly scattered pustules, those immediately anterior to the branchiae crownlike on a transverse raised ridge. *Color:* mantle transparent white peppered with black and flaked with white; rhinophores and branchiae fawn, peppered with black. *Rhinophores:* long, slender, with about twelve lamellae. *Branchiae:* large, feathery.

These dorids are found in shallow water on fringing reefs and on benches. They feed on the sponge *Halichondria dura*, and the color of the animals is apparently dependent on their food. When feeding they are light in color, when starved they become dark.

This species was described from the Hawaiian Islands.

Dendrodoris nigra (Stimpson, 1856). Fig. 151 A. (Synonyms: *Hexabranchus nebulosa* Pease, 1860; *Doridopsis macfarlandi* Ostergaard, 1955.) Length, to 30 mm; width, to 20 mm. *Animal:* ovate, extremely soft, often convex dorsally, the mantle margins thin and flaring; mantle usually smooth but occasionally with small pustules. *Color:* variable — usually black with white spots or brown with light yellow spots, mantle margins occasionally crimson, light blue, or light purple (juveniles orange); rhinophores matching the mantle in color but always with a white tip; branchiae dusky. *Rhinophores:* long and clublike. *Branchiae:* six to eight feathery gills.

D. nigra is the most commonly and abundantly occurring of the Hawaiian dorids, found clinging to the undersurfaces of rocks and rubble on limestone and detrital wave-washed benches, in tide pools, and in shallow waters shoreward of fringing reefs. The egg masses are broad, coiled, dark yellow ribbons. Juveniles are orange, the color change occurring when the animals are between 9 and 10 mm in length.

This is a ubiquitous species throughout the Indo-West Pacific, where it is known under a variety of names because of its variability in color and development of pustules.

Dendrodoris tuberculosa (Quoy and Gaimard, 1832). Fig. 151 C. (Synonym: *Doris rugosa* Pease, 1860.) Length, to 150 mm; width, to 60 mm. *Animal:* ovate, convex above, soft to the touch, mantle margins projecting as a thin flange; mantle ornamented with irregular, warty protuberances, those in the middorsal region larger and surrounded by smaller warts. *Color:* mantle gray-brown, shaded with darker brown which forms a network ramifying among the warty protuberances; rhinophores and branchiae colored as is the mantle; foot and ventral surface of mantle pale brown with a purple-brown streak running along the inner margin of the mantle. *Rhinophores:* stout, on fairly long peduncles, retractile into rounded sheaths. *Branchiae:* five feathery gills retractile into a large cavity ornamented with five conical, elevated flaps.

Large specimens (100 mm in length or more) have been found along the shoreline near Koloa, Kauai, in June and July; smaller animals occur in shallow water shoreward of the fringing reef at Nanakuli, Oahu, and on patch reefs in Kaneohe Bay, Oahu.

D. tuberculosa has been recorded from Mauritius (Bergh, 1889a), the Gilbert Islands (Eliot, 1906), and Japan (Baba, 1936; 1949).

Family **Polyceridae**

The members of this family include limaciform animals which feed on other opisthobranchs and ascidians. The branchiae form a nonretractile middorsal tuft.

Subfamily **Gymnodoridinae**

This subfamily encompasses animals with smooth, limaciform bodies and simply pinnate or bipinnate branchiae arranged in a circle or a semicircle about the median, middorsal anus. In *Gymnodoris,* the only genus apparently represented in the Islands, the body is somewhat swollen at midlength and tapers posteriorly as a narrow foot.

Gymnodoris alba Baba, 1930a. Fig. 152 D. Length, to 15 mm; width, to 3 mm. *Animal:* limaciform, the head forming a narrow cephalic hood with shallow serrations; oral tentacles lobiform and small; genital orifice immediately posterior to the cephalic hood. *Color:* white with orange-red spots; rhinophores with light yellow lamellae tipped with orange; branchiae white. *Rhinophores:* clublike, with ten lamellae. *Branchiae:* twelve simply pinnate gills flattened laterally and forming a horseshoe arrangement about the anus.

These opisthobranchs are uncommonly found on the undersurfaces of rocks on benches at Diamond Head and Kaimalino, Oahu. They feed on aeolids, *Favorinus* and *Aeolidiella.*

G. alba was described from the Philippines and has been reported from Japan (Baba, 1930a, 1949) and from the Indian Ocean (Eliot, 1910).

Gymnodoris bicolor (Alder and Hancock, 1866). Fig. 152 B. Length, to 22 mm; width, to 4 mm. *Animal:* limaciform, the head broadening into a wide cephalic hood with deep serrations; body occasionally with raised pustules; oral tentacles lobiform with rounded tips; genital orifice posterior to the branchiae. *Color:* cream to yellow with orange or orange-red spots; serrations of cephalic hood occasionally tipped with orange; rhinophores with light brown lamellae; branchiae cream to light yellow. *Rhinophores:* clublike with 15 to 20 lamellae. *Branchiae:* eight to ten simply pinnate gills arranged in a horseshoe about the anus.

These animals are common under rocks on benches both at Diamond Head and Kaimalino, Oahu. *G. bicolor* feeds on other gymnodorids, *G. okinawae* and *G. plebeia.*

This species has been recorded from South Africa (MacNae, 1958), and it probably occurs elsewhere in the Indo-West Pacific.

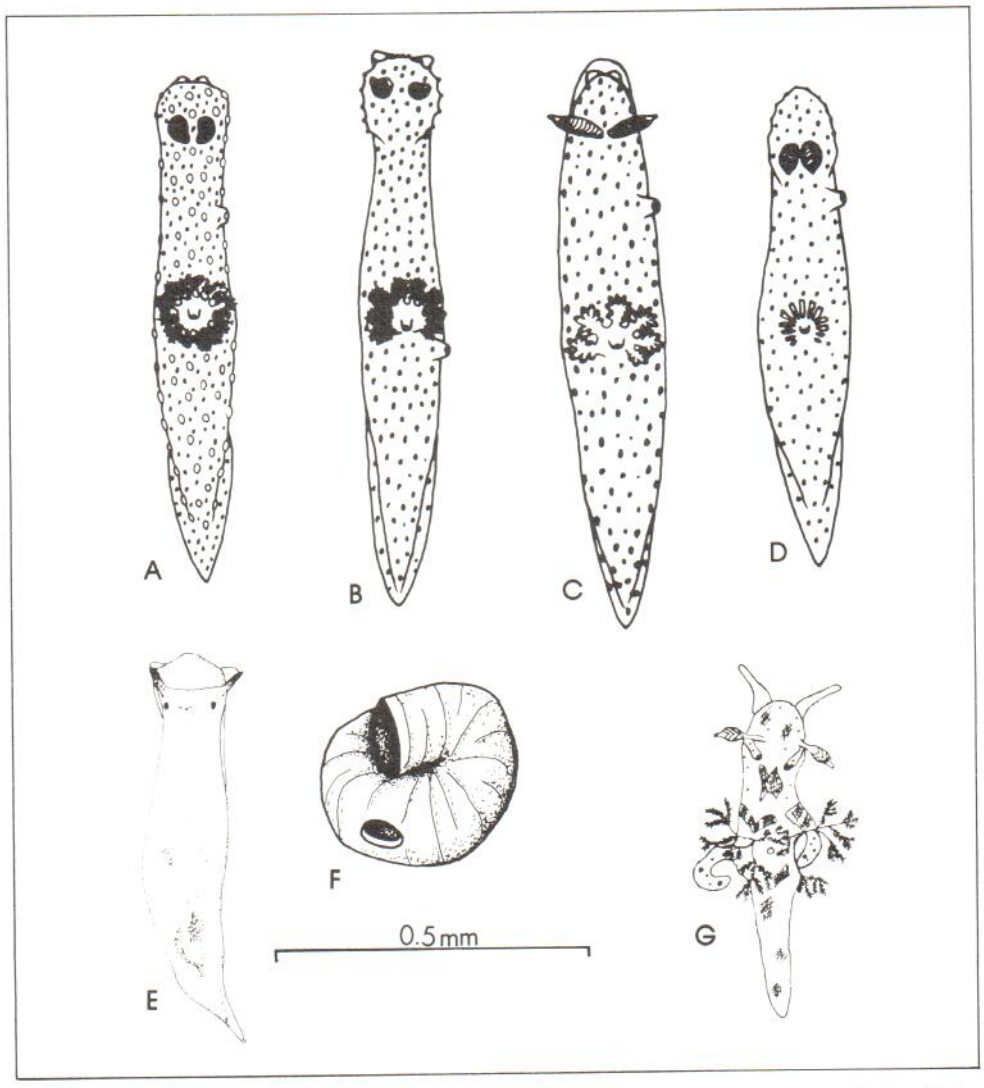


Figure 152.—A. *Gymnodoris okinawae*, length 25 mm. B. *G. bicolor*, length 15 mm. C. *G. plebeia*, length 12 mm. D. *G. alba*, length 12 mm. E. *Okadaia elegans*, length 3 mm. F. Bore hole in worm tube made by *O. elegans*. G. A goniodorid, *Trapania* sp., length 7 mm. (A - D and F from Young, 1966; G from Kay and Young, 1969.)

Gymnodoris okinawae Baba, 1936. Figs. 131 E; 152 A. Length, to 30 mm; width, to 4 mm. *Animal:* limaciform, the head forming a narrow cephalic hood with shallow serrations; with pustules often on the dorsum; oral tentacles lobiform and barely visible in dorsal view; genital orifice immediately posterior to the cephalic hood. *Color:* cream to light yellow with yellow-orange to red-orange spots, pustules white, often with red streaks laterally; rhinophores with yellow or light brown lamellae; branchiae cream to light yellow. *Rhinophores:* clublike with 15 to 20 lamellae. *Branchiae:* seven to twelve tripinnate branchiae forming a circle about the anus.

G. okinawae is a commonly occurring species, and animals are found under rocks on benches at both Diamond Head and Kaimalino, Oahu. The animals feed on various species of the sacoglossan genus *Elysia*.

G. okinawae was described from the Ryukyu Islands and is also known from Tanzania (Edmunds, 1971).

Gymnodoris plebeia (Bergh, 1877a). Fig. 152 C. Length, to 14 mm; width, to 3 mm. *Animal:* limaciform, without a cephalic hood, the foot extending anteriorly; oral tentacles small, lobiform and visible in dorsal view; genital orifice midway between the head and branchiae. *Color:* yellow with red-orange spots; rhinophores with light yellow lamellae; branchiae light yellow tipped with deep orange. *Rhinophores:* rodlike, set close together; with seven lamellae. *Branchiae:* four to six simply pinnate gills set in a horseshoe arrangement about the anus.

This species is uncommon, found under rocks on wave-washed benches at Diamond Head and Kaimalino, Oahu.

G. plebeia was described from the "Pacific Ocean"; *Trevelyana suggens* (Risbec, 1928) from New Caledonia appears to be a synonym.

Subfamily **Triophinae**

The members of this subfamily bear ramose or compound appendages.

Plocamopherus maculatus (Pease, 1860). Fig. 151 E, F. Length, to 21 mm; width, to 5 mm. *Animal:* limaciform, keeled and tapered posteriorly; with two processes on either side of the body, the anterior pair filamentous, the posterior pair with spherical ends; occasional tentacular filaments on the body wall; head developed as an oral veil somewhat broader than the rest of the body and fimbriated with tufts of filaments. *Color:* transparent white, spotted with orange and yellow; rhinophores light yellow-brown and tipped with white; branchiae freckled with brown and occasionally orange-yellow. *Rhinophores:* large, set laterally on the head; thickly lamellated. *Branchiae:* middorsal with a single rachis directed anteriorly and two posteriorly.

Of the animals recorded in recent years, one was found on the alga *Acanthophora* to which the animal adhered by its tail, two were under rocks in tide pools at Poipu, Kauai, and others on the alcyonacean, *Anthelia edmondsoni*.

P. maculatus was described from the Hawaiian Islands.

Family **Vayssiereidae**

These small dorids have limaciform bodies, simple, nonretractile rhinophores, and a middorsal anus but no gills.

Okadaia elegans Baba, 1931. Fig. 152 E-F. Length, to 4 mm; width, 1 mm. *Animal:* limaciform, with nonlamellate, noncryptic rhinophores and a middorsal anus. *Color:* light yellow-orange.

Specimens of this nudibranch are common on the undersurfaces of rocks along the shorelines of Oahu and Kauai. The animals are usually found near or on the calcareous

white tubes of spirorbid and serpulid polychaetes. They feed on the polychaetes by boring into the shells, forming a smooth, round, beveled hole presumably by chemical activity and mechanical rasping (Young, 1969). Development is direct, the young hatching as juveniles 10 days after spawning (Baba, 1937; Young, 1966).

O. elegans was described from Japan. It is also common at Enewetak, Marshall Islands (Kay and Young, 1969).

Family **Goniodorididae**

The members of this family resemble the polycerids in external appearance, but are distinguished by a pair of well-developed velar tentacles, various mantle appendages, and an "ingluvies buccalis." They may be suctorial feeders on ascidians. Most goniodorids are small (less than 10 mm in length), and because of their small size and cryptic coloration, they are easily overlooked. A small goniodorid is shown in Fig. 152 G.

Family **Phyllidiidae**

These opisthobranchs have oval bodies, the dorsum sculptured by large, sometimes pustulose tubercles, and the anus either dorsal or under the mantle posteriorly. They are conspicuously colored, with black bodies and yellow, blue, or pink tubercles. They are distinguished from the dorids by the absence of pinnate gills around the anus and the presence of secondary gills between the foot and the edge of the mantle. Two genera are distinguished here, *Fryeria* with the anus below the mantle skirt, and *Phyllidia* with the anus dorsal.

Fryeria rüppellii Bergh, 1889b. Fig. 153 B. Length, 15 mm; width, 8 mm. *Animal:* oval; mantle tubercles scattered, neither confluent nor symmetrically arranged except at the margin; tubercles flat, simple; anus beneath the mantle skirt posteriorly. *Color:* ground color black, tubercles pink; rhinophores white.

Specimens have been found at depths of 10 m on rocks and coral.

Edmunds (1972) has reviewed the records of *F. rüppellii,* and suggests that the animals reported from the Red Sea (as *Phyllidia pustulosa,* Rüppell and Leuckart, 1831), Tanzania (Edmunds, 1972), Mauritius (Bergh, 1889b), Madagascar (Risbec, 1929), and the Caroline and Marshall Islands (Marcus, 1965) may include more than one species. The Hawaiian animals appear to be similar to those described by Rüppell and Leuckart and Bergh (1889a), differing from those of Edmunds (1972) in their lack of confluent tubercles.

Phyllidia nigra Pease, 1868c. Fig. 153 D. Length, 8 mm; width, 3.5 mm. *Animal:* oval, slightly wider posteriorly than anteriorly; mantle tubercles confluent, arranged in symmetrical lines or ridges, one around the mantle edge, one parallel and three interrupted lines middorsally; anus dorsal, posterior. *Color:* ground color black, tubercles light pink.

These mollusks are uncommon, found at depths of about 10 m.

P. nigra was described from Tahiti.

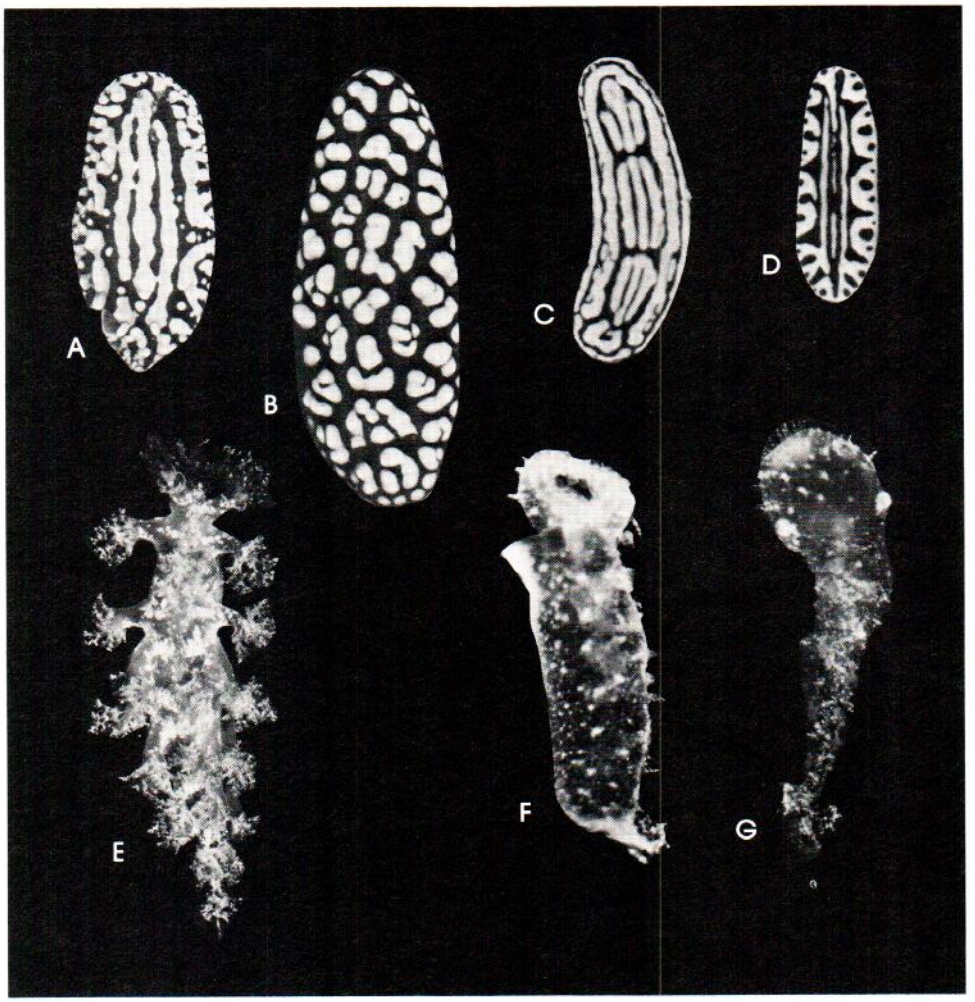


Figure 153.—A. *Phyllidia varicosa*, length 25 mm. B. *Fryeria rüppellii*, length 15 mm. C. *Phyllidia* sp., length 15 mm. D. *P. nigra*, length 8 mm. E. *Tritonia hawaiiensis*, length 30 mm. F, G. *Melibe pilosa* juveniles, length 15 mm. (Photo of *Tritonia* by D. Sarver.)

Phyllidia varicosa Lamarck, 1801. Figs. 153 A; 154 A. Length, 23 mm; width, 10 mm. *Animal:* elongate-oval; mantle tubercles arranged on three longitudinal ridges separated by grooves, with a number of shorter ridges at right angles to them. *Color:* black, longitudinal ridges gray-blue; tubercles bright orange; rhinophores orange; mantle and foot gray; foot with a black medial line.

These are the most common of the Hawaiian phyllidids, found at depths of 3 to 20 m on rocks. When disturbed the animals secrete a profuse mucus containing a toxin which affects lobsters, other crustacea, and small fish (Johannes, 1963).

P. varicosa is a conspicuous and common species in the Indo-West Pacific, recorded from Tanzania, the Philippines, Bismarck Archipelago, Palau, and the Solomon, Gilbert, and Marshall Islands (Edmunds, 1971).

Superfamily DENDRONOTACEA

The distinguishing features of these nudibranchs are the tubular rhinophore sheaths which are formed from part of the mantle, and lavish outgrowths on the dorsal surface of the body. In *Melibe* (Family Tethyidae) these processes are inflated, spoon-shaped paddles; in *Tritonia* (Family Tritoniidae) the processes are linearly arranged arborescent tufts. In a third family, the pelagic Phylliroidae (not known in Hawaii), the dorsal appendages are expanded and winglike. The Tethyidae are swimmers in shallow waters, often associated with *Sargassum* spp. which they resemble; the tritonids are sluggish animals apparently mostly associated with soft corals or alcyonarians.

Family **Tethyidae**

These nudibranchs are distinguished by their elongate, narrow bodies which are surmounted dorsally by large, inflated, paddle-shaped cerata. The head area is enormously expanded, forming a dilated funnel fringed with tentacles. The rhinophores are lamellate. The genital and anal openings are anterolateral on the right side, and the digestive gland is branched, ramifying into the cerata.

Melibe pilosa Pease, 1860. Fig. 153 F, G. Length, to 120 mm; width, to 73 mm across the cerata. *Animal:* slender, high and narrow; with six pairs of flat-topped cerata and with scattered, short papillae, some of which may be branched, on the body and on the cerata; genital aperture lateral, ventral to the first ceras on the right side; anus opening dorsolaterally between the second and third cerata; rhinophores with eight to ten lamellae on the club; sheath with a posterior crest; hood distensible, with several small papillae on the surface and five rows of cirri. *Color:* transparent, maculated with brown.

Specimens are common in shallow water on fringing reefs from January to May. Egg masses have been found in November and from February to May. The animals resemble species of *Sargassum* on which they are often found. They feed by using the hood as a cast net, apparently engulfing small crustacea.

Melibe pilosa was described from the Hawaiian Islands but is widespread in the Indian and Pacific oceans, and has most recently been reported from Tanzania (Edmunds and Thompson, 1972).

Family **Tritoniidae**

These nudibranchs have elongate bodies with branching, arborescent tufts of branchiae extending in a linear series from each side of the body. The rhinophores are in the form of a simple club surrounded by pinnate filaments.

Tritonia hawaiiensis Pease, 1860. Fig. 153 E. Length, to 30 mm; width, about 20 mm. *Animal:* elongate; with seven branched papillae on each side; rhinophores retractile into basal sheaths, the sheaths fringed basally and with a cuplike extension; foot narrow. *Color:* orange-pink, dorsally banded with a light band extending from the head to the posterior end; branchiae light brown, sometimes tipped with green.

These nudibranchs are found with alcyonacean *Anthelia* on which they graze. The animals swim with an anterior-posterior undulating motion.

T. hawaiiensis was described from the Hawaiian Islands.

Superfamily ARMINACEA

Family **Arminidae**

Included in this group of nudibranchs are forms with a variety of shapes and external appendages, some resembling dorids, others with dorsal ceratal processes like the aeolids. Their common features are rhinophores which lack sheaths, the anal papilla either dorsal or lateral on the right but quite far forward on the body, and a much-branched digestive gland. In the Arminidae, the only family with representatives in Hawaiian waters, the animals are characterized by external pallial leaflets. In these nudibranchs feeding is apparently suctorial.

Dermatobranchus rubida (Gould, 1852). Fig. 154 B. Length, 60 mm; width, 30 mm. *Animal:* elongate, slender, with lamellae extending the length of the body; rhinophores short. *Color:* lamellae and foot white, finely peppered with crimson-purple; rhinophores crimson.

These nudibranchs are found on fringing reefs on Oahu and are apparently seasonally abundant.

D. rubida was described from the Hawaiian Islands. Although Gould's description included a "lake-red" foot, other aspects of the description are so clear that the animals are assigned Gould's name without hesitation.

Superfamily AEOLIDACEA

Aeolids are distinguished by their long, slender bodies which bear projections, cerata, on either side of the dorsal body wall. The cerata contain diverticula of the digestive gland, and can be autotomized and regenerated in some species; in others autotomy and regeneration occur only rarely (Edmunds, 1966). Aeolids are associated with coelenterates, sea anemones, hydroids, and corals, upon which they feed. In some, the tips of the cerata are modified as cnidosacs which accumulate the nematocysts of the coelenterate prey; the nematocysts may be released as a defensive mechanism when the animals are disturbed.

Aeolids are often brilliantly colored, with red, orange, yellow, and even blue pigments. Edmunds (1966) suggests the color may be cryptic or warning, or associated with diet. The head bears both cephalic tentacles and rhinophores, the latter simple clubs, perfoliate, annulate, or laminate, but never enclosed in sheaths as they are in other nudibranchs. The foot is about the same breadth as the body, but the anterior corners may be produced as tentacular projections.

The aeolids are apparently a polyphyletic taxon, and the classification schemes that have been suggested are not entirely satisfactory. The basis of most of the

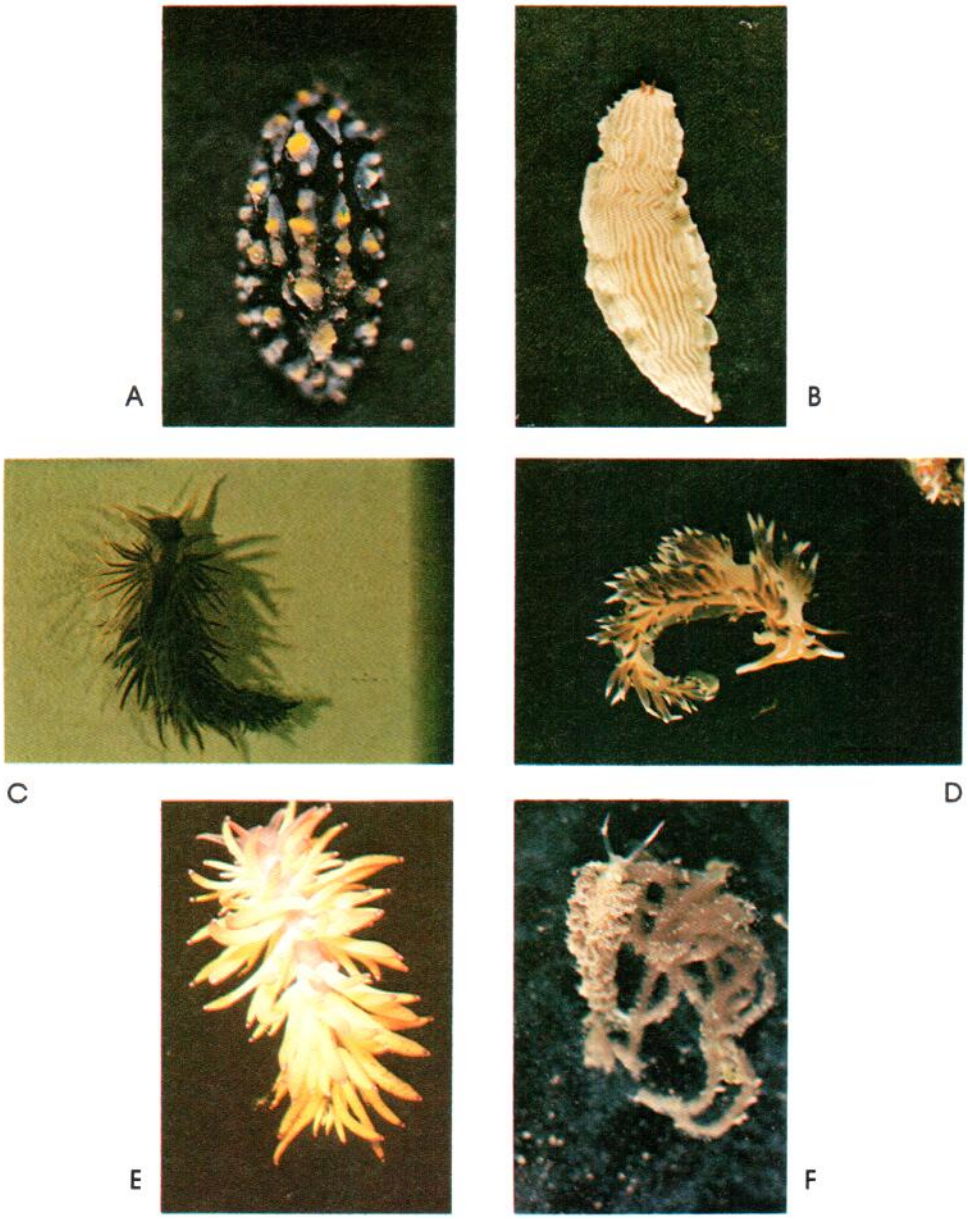


Figure 154.—A. *Phyllidia varicosa*, length 25 mm. B. *Dermatobranchus rubida*, length 60 mm. C. *Herviella mietta*, length 28 mm. D. *Caloria militaris*, length 22 mm. E. *Phestilla melanobrachia*, length 32 mm. F. *Favorinus japonicus* feeding on an aplysid egg mass, length 15 mm. (E. by S. A. Reed.)

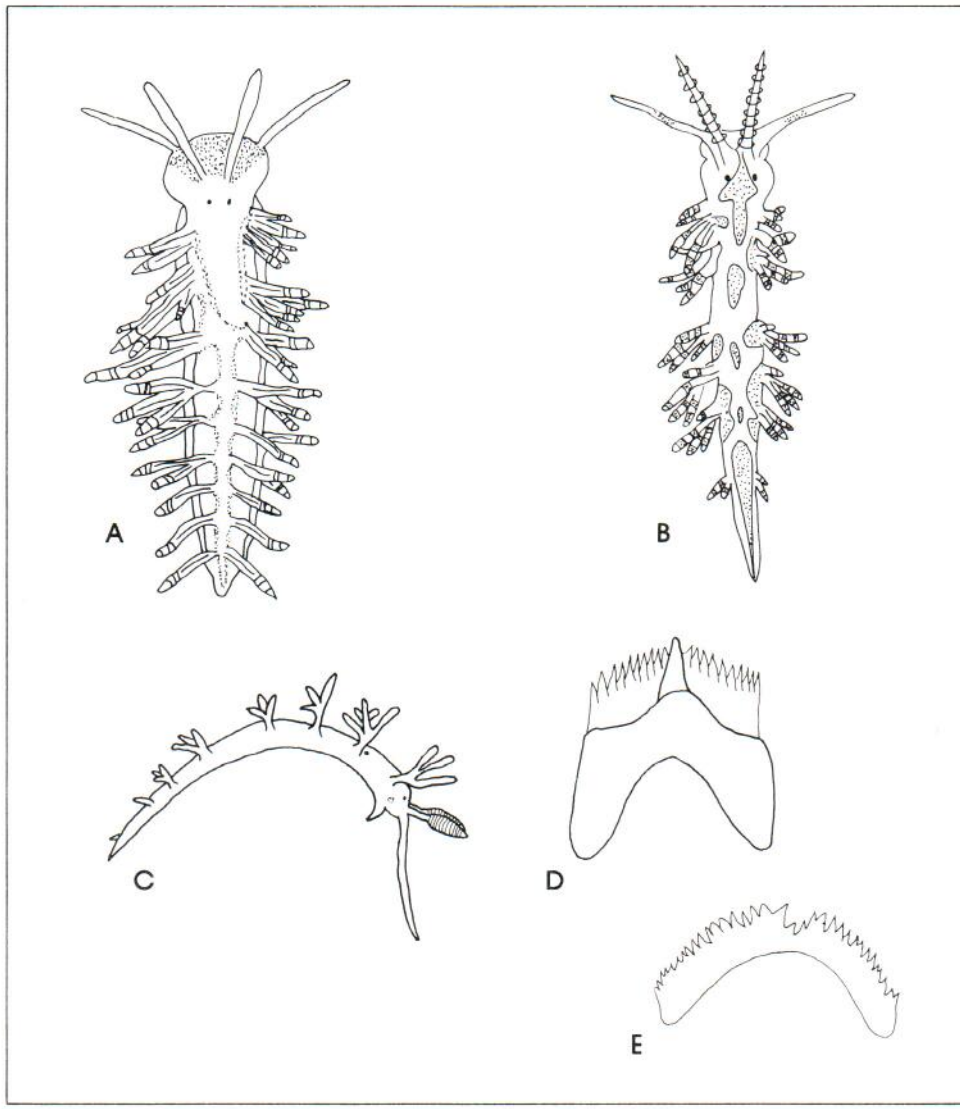


Figure 155.—A. *Cuthona perca,* length 8 mm. B. *C. pinnifera,* length 12 mm. C. *Flabellina* sp., length 12 mm. D. Cuspidate radula tooth. E. Pectinate radula tooth. (From Gosliner, 1973.)

classificatory schemes is the arrangement of the digestive gland and the position of the anus. The radula is reduced to a narrow ribbon, sometimes with only a single file of teeth in it (the uniseriate condition). The teeth are pectinate or cuspidate (Figure 155 D, E). Jaws are also present and often better developed than the radulae. But neither jaws nor radular teeth are especially useful in classification, which is based on several anatomical features of the animals.

In the following descriptions details of cerata, digestive gland and position of genital pore are from Gosliner (1973, In press).

Family **Coryphellidae**

In these aeolids the body is elongate and compressed, and the cerata are borne on low elevations at the dorsal margin of the body. The radular teeth are uniseriate.

Flabellina sp. Fig. 155 C. Length, to 15 mm. *Animal:* cephalic tentacles extremely long, more than half the length of the body; rhinophores bulbous and perfoliate; foot corners short, sharply recurved; cerata joined at the bases in groups of two or three with a common insertion. *Color:* body white; rhinophores golden brown anteriorly, red brown at the base; cerata white with a subapical orange ring.

These aeolids are usually associated with hydroids, and their egg masses are found on bryozoans but their feeding habits are not known (Gosliner, 1973). They are preyed on by *Gymnodoris*.

Gosliner (In press) notes that *Flabellina* sp. superficially resembles *Coryphella ornata* Risbec, 1928, from New Caledonia, but is distinguished by the shape and configuration of the radular teeth and jaws. The Hawaiian animals are, however, similar to those described by Baba (1936 as *Coryphella*) and Abe (1964 as *Flabellina*) from Japan, which were also referred to *C. ornata* (Gosliner, 1973).

Additional Record

Samla annuligera Bergh, 1900, was described from Laysan but has not since been recognized.

Family **Cuthonidae**

The aeolids in this family are, for the most part, relatively small and compressed. The foot is usually rounded in front, the rhinophores simple, the cerata fusiform or clavate, and the digestive diverticula are arranged in single rows.

Cuthona perca (Marcus, 1958). Fig. 155 A. Length, 5 to 15 mm. *Animal:* head rounded; cephalic tentacles and rhinophores smooth, the cephalic tentacles shorter than the rhinophores; anterior margin of foot rounded; cerata elongate, two rows associated with the right liver, five to ten pairs of cerata with the left digestive gland. *Color:* body translucent white with scattered opaque white pigment and dark olive green dots; cerata with olive green pigment in the central core.

All the animals for which there are records were found on the floating docks and in the sea water tables at the Hawaii Institute of Marine Biology, Coconut Island, in Kaneohe Bay, Oahu; the aeolids were found between July and October (Gosliner, 1973).

C. perca was described from Brazil, Jamaica, and Florida.

Phestilla melanobrachia Bergh, 1873a. Fig. 154 E. Length, 10 to 40 mm. *Animal:* flattened dorsoventrally; cephalic tentacles and rhinophores smooth, about one-quarter the length of the body; cerata long, arranged on ridges running on a diagonal anterior to posterior. *Color:* usually orange or orange and yellow, but may be brown or pink depending on diet (Harris, 1968).

These aeolids are found at depths of 2 to 10 m where they feed on the colonial, bright orange coral *Tubastrea aurea*, and at greater depths (to 30 m) where they feed on other colonial corals (Harris, 1968). In the laboratory the aeolids which feed on orange corals are distinctly orange, but when they feed on other corals the orange pigment may be replaced.

P. melanobrachia was described from the Philippines, and has been recorded from Singapore, southern Japan, and Okinawa (Harris, 1968).

Phestilla sibogae Bergh, 1905. Fig. 156 E. (Synonym: *Aeolidiella edmondsoni* Ostergaard, 1955.) Length, to 30 mm. *Animal:* broad and stout, head rounded; cephalic tentacles and rhinophores smooth and conical; anterior margin of foot rounded and broadened as an oral veil; cerata numerous and with several inflations along their length. *Color:* translucent white with opaque white markings on the head and cerata.

The cerata of these aeolids resemble the polyps of the corals *Porites compressa* and *P. lobata* on which the animals feed; the brown color of the digestive gland is due to the zooxanthellae from the *Porites*. Although animals are uncommon in the field, numerous specimens appear from the heads of *Porites* in sea water tables in the laboratory (Hadfield and Karlson, 1969). The aeolids feed voraciously on the coral polyps and deposit their egg masses, fan-shaped structures more than 1 cm in diameter, on the undersurfaces of coral colonies. The veliger stage is reached within three days after spawning, hatching occurs about the ninth day (Hadfield, 1972). Generation time is about 38 days from egg to egg, and the animals live up to five months (Harris, 1975). Metamorphosis occurs only in the presence of living *Porites compressa* (Hadfield and Karlson, 1969).

P. sibogae was described from the Timor Sea and has also been recorded from Palau (Kawaguti, 1943); *Aeolidiella edmondsoni* was described from the Hawaiian Islands.

Additional Records

Cuthona pinnifera (Baba, 1949) (Fig. 155 B), a small (length 7 mm) white aeolid was found associated with the plumularid hydroid *Halopteris diaphana* in Kaneohe Bay, Oahu, in August, 1972 (Gosliner, 1973). A small aeolid described and figured by Edmondson (1946) has been tentatively identified as *Embletonia gracile* Risbec, 1928, described from New Caledonia (Gosliner, 1973).

Family **Facelinidae**

In the facelinids the cerata occur in regular rows. The rhinophores are smooth, distinguished by swellings along their length, or they are perfoliate. The foot corners are produced as tentacular processes or rounded. These aeolids feed on the hydranths of small hydroids or sea anemones. The radular teeth are uniseriate, shaped like a horseshoe.

Caloria militaris (Alder and Hancock, 1866). Fig. 154 D. (Synonym: *Learchis indica* Bergh, 1896, Baba, 1969.) Length, 7 to 35 mm. *Animal:* long and slender;

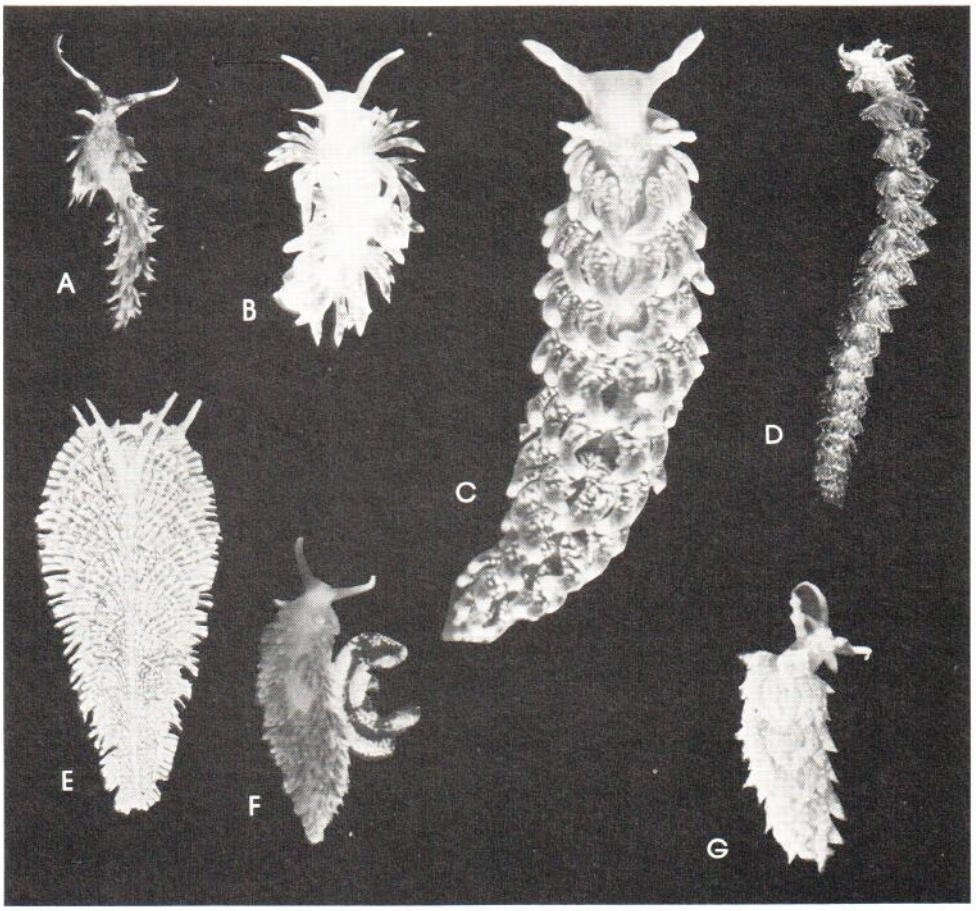


Figure 156.—A. *Facelinella semidecora*, length 10 mm. B. *Berghia major*, length 20 mm. C. *Spurilla japonica*, length 25 mm. D. *Pteraeolidia ianthina*, length 75 mm. E. *Phestilla sibogae*, length 25 mm. F. *Aeolidiella takanosimiensis*, length 12 mm and egg mass. G. *Favorinus japonicus*, length 12 mm.

cephalic tentacles and rhinophores smooth, cephalic tentacles longer than rhinophores and acute; anterior foot corners tentaculate, elongate; cerata arranged in horseshoe-shaped rows with a single arch in the anterior digestive gland followed by five to seven arches in the posterior diverticulum. *Color:* vivid and variable — body translucent yellow-white, head region orange-red with opaque white markings; cephalic tentacles opaque white three-quarters of their length; rhinophores translucent white with a median band of opaque white and an apical band of red; cerata bright red from the base to the midpoint, becoming blue and terminating with a white apex.

These aeolids are common in Kaneohe Bay, Oahu, throughout the year. They feed on the hydroid *Halocordyle tiarella*, and have been found at depths to 12 m (Gosliner, 1973).

C. militaris was described from India, and has been recorded from Ceylon, Australia, Amboina, Japan, New Caledonia, and New Zealand (Burn and Natarajan, 1970), and Enewetak, Marshall Islands.

Facelinella semidecora (Pease, 1860). Fig. 156 A. Length, 6 to 12 mm. *Animal:* thin, elongate; cerata short, arranged in rows, five in the anterior liver and seven in the right posterior liver, the latter divided into two distinct groups; rhinophores annulated with two to five rings of varying size; cephalic tentacles sharply tapered, one-third the length of the rhinophores; anterior foot corners tentacular; genital pore ventral to posterior portion of right digestive gland; anus anterior to second ceratal row of posterior digestive gland. *Color:* translucent white, maculated with opaque white, with two vermilion lines on the head and along the body; cephalic tentacles banded with opaque white and red with a single band of each near the center and a longer band of white near the apex; apical portion of rhinophores banded with opaque white; cerata brown internally, opaque white near the apices.

This is one of the most commonly encountered aeolids in shallow waters, found under rocks shoreward on fringing reefs, on solution benches and in tide pools. Animals and their egg masses have been found throughout the year.

F. semidecora was described from the Hawaiian Islands and has also been recorded from Japan (Baba, 1949; 1965 as *F. anulifera*).

Favorinus japonicus Baba, 1949. Figs. 154 F; 156 G. Length, 8 to 17 mm. *Animal:* slender, elongate; cephalic tentacles long and tapering; rhinophores conical with two bulbous swellings, one near the middle, the other below the apex; foot corners tentacular; cerata in seven pairs of rows, recurved and papillate. *Color:* white, pink, or green, apparently dependent on the food.

These aeolids are found on fringing reefs and benches where they feed on the eggs of opisthobranchs, especially those of *Aplysia, Dolabrifera,* and *Melibe*. The pigment of the food is deposited in the cerata, resulting in the different colors displayed by the aeolids.

F. japonicus was described from Sagami Bay, Japan, and has also been recorded from Guam (Carlson and Hoff, 1973).

Herviella mietta Marcus and Burch, 1965. Fig. 154 C. Length, 7 to 40 mm. *Animal:* short, relatively broad; cerata long and thin, arranged in five to six rows, with a single row in the right anterior digestive gland; rhinophores smooth and conical; cephalic tentacles long and slender, approximating the rhinophores in length; genital aperture ventral to first row of cerata; anus posterior to second ceratal row. *Color:* dark green to black with translucent white; the dark pigment most pronounced in the head region; foot translucent white.

These aeolids were reported on the reef flat at Kewalo Basin, Oahu, feeding on the sea anemone *Anthopleura nigrescens* which they resemble in color and form (Rosin, 1969, as *Herviella* sp.). Specimens have been found in most months of the year.

H. mietta was described from Enewetak, Marshall Islands.

Additional Record

A single specimen of *Noumeaella* sp. cf. *rehderi* Marcus, 1965, a small (11 mm), slender, white aeolid with long, fusiform, recurved cerata arranged in five groups in horseshoe-shaped arches, is reported from a subtidal coral community at Keahou Bay, Hawaii (Gosliner, In press).

Family **Glaucidae**

The glaucids are pelagic, found in surface waters of tropical oceans, floating ventral surface uppermost. Among their adaptations to a pelagic life are clustered cerata which extend winglike from the body, their predominantly blue color, and the presence of a gas bubble in the stomach which presumably increases their buoyancy. Glaucids feed on siphonophore coelenterates such as the "Portuguese man-of-war," *Velella, Porpita,* and *Physalia*. Nematocysts from their prey accumulate in the cerata and may be discharged when the hosts are disturbed. Swimmers at Port Stephens, New South Wales, were unpleasantly stung by nematocysts from the nudibranchs in 1968 (Thompson and Bennett, 1970).

There are two genera: *Glaucus* with a single row of cerata on each side and a large, spined penis; and *Glaucilla* with the cerata arranged in more than one series and with the penis lacking a spine.

Glaucus atlanticus Forster, 1777. Fig. 131 B. (Synonym: *Glaucus longicirrus* Bergh, Edmondson, 1946.) Length, 7 to 30 mm. *Animal:* narrow but with palplike cerata in two to three groups on both sides of the body; rhinophores and cephalic tentacles short; anterior foot corners simply rounded; penis armed with a dark brown penial spine. *Color:* dark blue to purple and silver.

These aeolids are commonly washed up on beaches after storms.

G. atlanticus is circumtropical in distribution.

Family **Pteraeolididae**

The aeolids in this family are characterized by flaplike cerata which form conspicuous extensions of the body wall.

Pteraeolidia ianthina (Angas, 1864). Fig. 156 D. Length, to 100 mm. *Animal:* body long and slender, rather like a centipede; with 5 to 18 pairs of winglike ceratal groups; cephalic tentacles elongate; rhinophores perfoliate; anterior foot corners tentacular. *Color:* variable — general body color greenish, cephalic tentacles green banded with opaque white and black; dorsal surface with gold reticulations or white patches; cerata green to bluish-purple, often with opaque white pigment and a white, yellow or gold apex.

These aeolids are usually found at depths of 10 to 20 m where they appear to be associated with the alcyonacean *Anthelia edmondsoni,* which they resemble in color.

P. ianthina was described from Australia; it is also known from the Red Sea (Marcus and Marcus, 1959), New Caledonia (Risbec, 1928; 1953), the Philippines (Bergh, 1870a), and Micronesia (Marcus, 1965).

Family **Aeolidiidae**

The aeolids in this family are relatively large, the cerata are arranged in two or more rows, and the radula consists of a single row (uniseriate condition) of comblike teeth.

Aeolidiella takanosimiensis Baba, 1930c. Fig. 156 F. Length, to 21 mm. *Animal:* slender, elongate; cerata with four to eight rows in the right anterior digestive gland in a single group, with 11 to 16 in the posterior digestive gland grouped in one to four rows; cephalic tentacles elongate; rhinophores smooth and conical; anterior foot corners short and tentacular; genital pore ventral to the first group of cerata; anus in the first ceratal group of the posterior digestive gland. *Color:* translucent white with varying amounts of orange in the head region, often with two opaque white spots posterior to the rhinophores; rhinophores encircled with red-orange; cerata brick red to dark brown, usually with a subapical white band.

These aeolids and their egg masses have been found throughout the year under rubble shoreward on fringing reefs, and in tide pools on Kauai.

A. takanosimiensis was described from Japan, and has also been recorded from southern California (Sphon, 1971).

Baeolidia nodosa (Haefelfinger and Stamm, 1958). (Not figured.) Length, 26 mm. *Animal:* long and slender; cephalic tentacles elongate; rhinophores densely papillate on posterior side, apex sharply acute; anterior foot corners sharply tentacular with a deep groove across the width; anterior right digestive gland with only two cerata, posterior digestive gland with 16 cerata; cerata irregular in shape, generally dorsoventrally flattened, some papillate. *Color:* brown reticulated with translucent white; cephalic tentacles and rhinophores brown, maculated with white; dorsal surface of body with white ocellae circled with blue-green and yellow; cerata yellow-brown reticulated with white, banded with white subapically, apex white.

Specimens have been found on sand flats in Kaneohe Bay (Gosliner, 1973) and in tide pools on Kauai.

B. nodosa was described from the Mediterranean.

Berghia major (Eliot, 1903). Fig. 156 B. Length, to 100 mm. *Animal:* body slender, cerata long and extending from body; rhinophores usually densely papillate, but occasionally almost lacking papillae; cephalic tentacles extremely elongate; anterior foot corners elongate, tentacular, border with a notch; cerata numerous, dorsoventrally flattened, cerata of anterior right digestive gland in a single horseshoe-shaped arch, cerata posterior to second to fifth arches in linear rows; genital pore ventral to anterior portion of anterior right digestive gland; anus within first horseshoe of posterior right digestive gland. *Color:* variable — translucent white, golden brown, dark gray-green; head region may have a spot of dark pigmentation; cerata usually ornamented with opaque white spots and subapical blue rings.

These aeolids are common shoreward of fringing reefs, on patch reefs in Kaneohe Bay, Oahu, and in tide pools on Kauai. Eliot's (1903) description of his specimens remains apt: "the whole animal closely resembled a kind of detachable sea anemone. . . ." The aeolids feed on the sea anemones *Boloceroides* and *Aiptasia;* the cephalic tentacles are used in establishing contact with the sea anemones and the tentacles firmly grasp the anemone while engulfing it (Gosliner, 1973).

B. major was described from Tanzania and has been recorded from Japan (Baba, 1933), Australia (Allan, 1947), New Zealand (Morton and Miller, 1968), and Mexico (Farmer, 1966, as *Berghia amakusana fide* Gosliner, 1973).

Spurilla japonica (Eliot, 1913). Fig. 156 C. Length, to 30 mm. *Animal:* stout, broad; cephalic tentacles short, markedly constricted in the middle; rhinophores short, bulbous medially; anterior foot corners rounded; cerata in 9 to 11 groups, all curved inward toward the axis of the body. *Color:* general body color translucent white; cerata olive-green flecked with white and with a solid white apex; with a spot of orange or red on the head between the rhinophores.

These aeolids are found in tide pools, on solution benches and on fringing reefs most months of the year.

S. japonica was described from Japan.

Additional Record

A single specimen of the circumtropical species, *Spurilla neapolitana* (Delle Chiaje, 1841) has been recorded from Kewalo Basin, Oahu (Gosliner, 1973).

Superfamily ONCHIDIACEA

Family **Onchidiidae**

This group of sluglike mollusks was included among the Pulmonata by earlier workers because of the presence of a "lung" or pulmonary sac, vascularized tissue in the mantle cavity at the posterior end of the body. Fretter (1943) showed that the tissue is not homologous with that of the pulmonate lung, and that various other features of these animals suggested that they were more meaningfully classed with the Opisthobranchia. However, the limits of the group have not yet been satisfactorily defined: Keen (1971) includes them in the order Gymnophila (= Soleolifera) with two families of terrestrial slugs in the subclass Opisthobranchia; Solem (1974) separates them as an order within the subclass Pulmonata.

The onchidids are intertidal marine slugs, oval in outline, with a dorsally arched notum bearing warts and papillae, glands secreting noxious fluids at the sides of the body, and tentacles bearing eyes at their tips.

Onchidium verruculatum (Cuvier, 1830). Fig. 157 E. Length, 30 mm; width, 20 mm. *Animal:* oval, the notum projecting beyond the foot; head with retractile tentacles bearing eyes and a pair of oral lappets; notum with simple and compound tubercles, some of them branched; dark gray or olive.

These slugs are common in the intertidal, found at the base of the nip on solution benches, on large boulders on fringing reefs, and on boulders on basalt shorelines. They are active grazers, feeding on algae such as *Ahnfeltia*.

O. verruculatum is apparently distributed throughout the Indo-West Pacific, from the east coast of Africa to Australia and New Caledonia (Hoffmann, 1928).

Subclass PULMONATA

The Pulmonata include a large group of air-breathing gastropods in which the mantle cavity is heavily vascularized rather than containing a gill or ctenidia. Pulmonates are hermaphroditic and display elaborate arrangements of the reproductive system associated with the production and accumulation of eggs and sperm. Pulmonate shells, compared with those of the prosobranchs, are rather conservative in form and sculpture. They are characterized by the presence of complex teeth and ridges in the aperture, columellar plaits, and varying degrees of shell resorption internally. There is no operculum.

The subclass is usually divided into two well-defined orders, the aquatic Basommatophora with one pair of tentacles with an eye near the base, as in the prosobranchs, and the terrestrial Stylommatophora with two pairs of tentacles of which the posterior pair is mounted with eyes. The order Basommatophora encompasses about 48 genera in four superfamilies, of which the Siphonariacea and Melampacea occur in Hawaii. The Stylommatophora comprises a vast assemblage of perhaps 600 genera grouped in 14 superfamilies, including the well-known Hawaiian land snail families, Achatinellidae and Amastridae.

Order BASOMMATOPHORA

Superfamily MELAMPACEA

Family **Melampidae**

The Melampacea include the most primitive existing pulmonates, the Melampidae, which are intertidal and supratidal, as well as the terrestrial pulmonate family Chilinidae and the estuarine family Otinidae. Only the Melampidae is represented along Hawaiian shorelines.

Melampids exhibit many structural features which reflect their prosobranch origins as well as others associated with their peculiar habits and mode of life, such as varying degrees of resorption of the internal shell and the tendency of the foot to become deeply cleft transversely into an anterior third and longer posterior part.

All the Hawaiian representatives of the family are found in a similar habitat: high along shorelines, shoreward of limestone benches in the supratidal or spray zone which is beyond the influence of tides, and around anchialine ponds on lava flows. Melampids are gregarious, and two or three species are found in each colony, along with the amphibious prosobranch *Assiminea nitida*.

Allochroa bronni (Philippi, 1846a). Fig. 157 F, G. (Synonyms: *Ellobium brownii* "Philippi" H. and A. Adams, 1853; *Auricula sandwichiensis* Souleyet, 1852.) Length, 10 mm; diameter, 6 mm. *Shell:* ovate-conic; faintly striate; white broadly banded with brown. *Spire:* minute, attenuate; last whorl the largest; suture indistinct. *Sculpture:* microscopically spirally striate. *Aperture:* narrow; outer lip thin, with a single fold within; columella with two prominent folds and a third, smaller twisted fold near the base. *Color:* gray-white, spirally banded with two broad, sometimes confluent blackish-brown bands.

These melampids are found seaward of *Melampus, Pedipes,* and *Laemodonta,* often buried in gravel in high tide pools and along rocky shores.

A. bronni was described from the Hawaiian Islands.

Laemodonta octanfracta (Jonas, 1845). Fig. 157 B. (Synonyms: *Plectotrema clausa* H. and A. Adams, 1853; *Auricula striata* Philippi, 1846a.) Length, 12 mm; diameter, 7 mm. *Shell:* ovate-conical; with flat spiral cords; dark brown. *Spire:* attenuate, longer than aperture; last whorl the largest; suture indistinct. *Sculpture:* broad, low, flat, spiral cords, of which there are five or six on each whorl. *Aperture:* small; outer lip sharp and with a single plait within; columella with three plaits, the apical lamelliform, the abapical toothlike; base often with an umbilical depression. *Color:* dark red-brown.

These melampids are found with *Melampus* and *Pedipes* under rocks and rubble in the supraspray zone.

This species is found throughout the Indo-West Pacific, from Mauritius and the Seychelles to Hawaii (Hubendick, 1956).

Melampus castaneus (Muhlfeld, 1816). Fig. 157 H. Length, 13 mm; diameter, 7 mm. *Shell:* ovate; broad at the apex; smooth; brown. *Spire:* protoconch minute, attenuate; last whorl the largest; shoulder angulate to rounded; suture impressed. *Sculpture:* microscopic growth striae only on the abapical whorls, apical whorls and base finely striate. *Aperture:* narrow; outer lip with six or seven plaits; columella with one large fold and two smaller apical folds. *Color:* light to dark brown; columellar folds cream, denticles of inner lip white; inside rim of outer lip edged with brown.

These melampids are found with *Laemodonta* and *Pedipes* in the supraspray zone under rocks and rubble.

M. castaneus is known throughout the tropical Pacific.

Melampus parvulus Pfeiffer, 1846. Fig. 157 D. Length, 10 mm; diameter, 6 mm. *Shell:* ovate; broad at the apex; smooth; brown. *Spire:* minute, attenuate; last whorl the largest; suture impressed, irregular. *Sculpture:* microscopic growth striae only. *Aperture:* narrow; outer lip thin, with four or five ridges; columella with one strong fold and often with another weaker fold. *Color:* light to dark brown; periostracum thin, darker than shell.

This species is common under rocks and rubble high in the supraspray zone.

M. parvulus was described from the Hawaiian Islands, and is also known from the Torres Strait, New Caledonia, Samoa, and Wallis Island (Garrett, 1857).

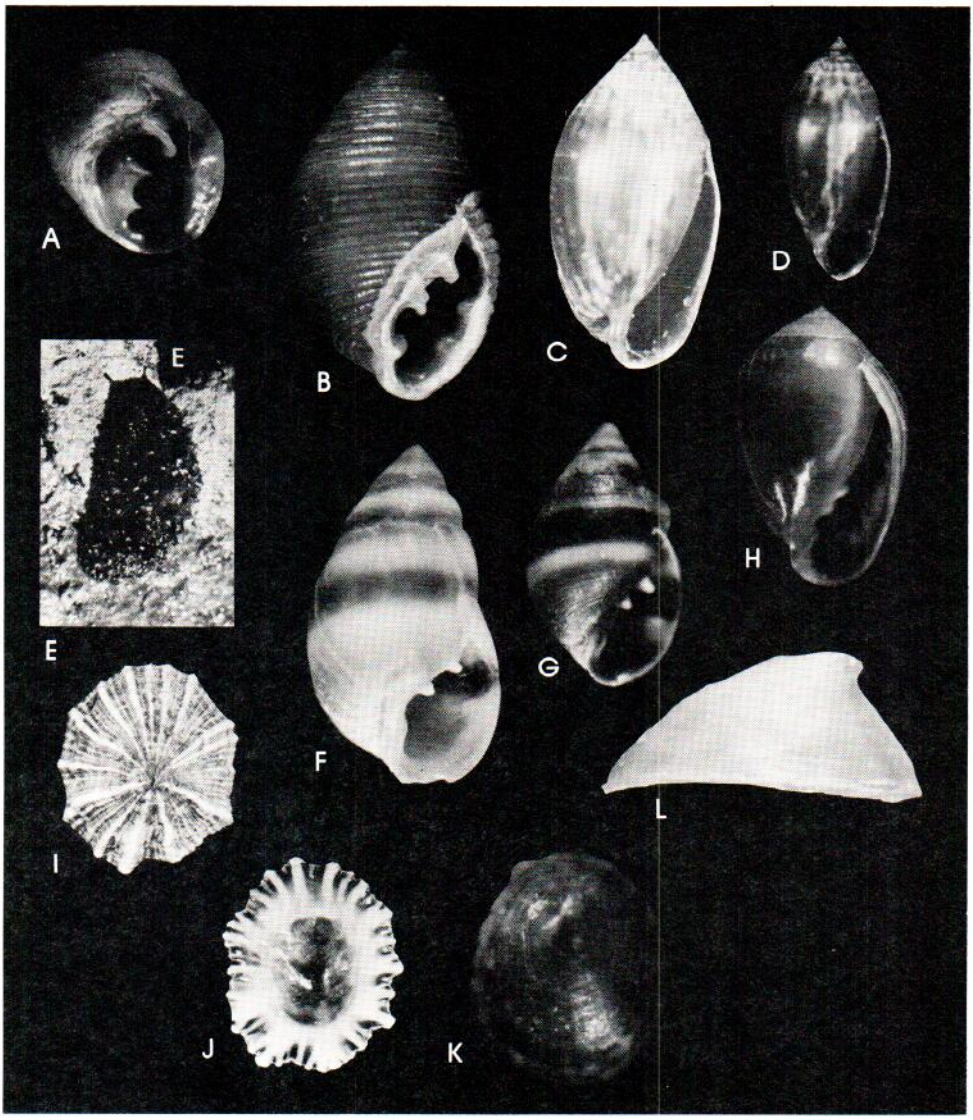


Figure 157.—A. *Pedipes sandwicensis*, length 2 mm. B. *Laemodonta octanfracta*, length 12 mm. C. *Pira sculptus*, length 11 mm (lectotype, *Melampus semiplicatus*). D. *Melampus parvulus*, length 10 mm. E. *Onchidium verruculatum*, length 22 mm. F, G. *Allochroa bronni*, two color forms, (F) 8 mm, (G) 10 mm. H. *Melampus castaneus*, length 13 mm. I, J. *Siphonaria normalis*, length 21 mm. K, L. *Williamia radiata*, length 5 mm.

Pira sculptus (Pfeiffer, 1850). Fig. 157 C. (Synonyms: *Melampus fricki* Pfeiffer, 1850; *M. semiplicatus* Pease, 1860.) Length, 11 mm; diameter, 6 mm. *Shell:* ovate-elongate, shoulder rounded; smooth; dark brown. *Spire:* acute; teleoconch of eight or nine whorls; last whorl the largest, rounded at the shoulder; suture indistinct. *Sculpture:* microscopic growth striae only. *Aperture:* narrow, outer lip thin, with three folds; columella with two folds at the base. *Color:* dark brown.

These melampids are uncommon, found only occasionally with *M. parvulus*.

P. sculptus was described from the Admiralty Islands; Garrett (1857) records it from New Caledonia and Fiji. *Melampus fricki* and *M. semiplicatus* were described from the Hawaiian Islands.

Pedipes sandwicensis Pease, 1860. Fig. 157 A. Length, 2 mm; diameter, 2 mm. *Shell:* rotund, inflated; with spiral grooves; brown. *Spire:* depressed; last whorl the largest; suture impressed. *Sculpture:* spiral grooves evenly spaced over the whorls. *Aperture:* large, with three heavy columellar folds, the uppermost the largest. *Color:* dark brown.

These melampids are common with *Melampus* and *Laemodonta* beneath rocks and rubble in the supratidal.

P. sandwicensis was described from the Hawaiian Islands.

Additional Record

Blauneria gracilis Pease, 1860, with a small (5 mm) subulate, sinistral, transparent shell has not been recorded since its original description.

Superfamily SIPHONARIACEA

Family **Siphonariidae**

Siphonarid shells are limpetlike, distinguished from those of patellid limpets by the sinus at the edge of the shell, on the right side. They resemble the limpets, however, in growth form; and shell height, as in the limpets, appears to be dependent on exposure to wave action.

Siphonaria normalis Gould, 1846. Fig. 157 I, J. (Synonym: *Siphonaria amara* (Nuttall MS) Reeve, 1856.) Length, 20 mm; diameter, 10 mm; height, 7 mm. *Shell:* conical; slightly broader posteriorly than anteriorly; apex subcentral. *Sculpture:* widely separated radiating ribs interspersed with finer ribs; ribs projecting beyond the margins of the shell. *Interior:* siphon well developed on the right; muscle scar horseshoe-shaped; smooth and glossy. *Color:* dark gray, ribs white, interior glossy black.

These limpets live in the intertidal, below the nerites. They are most active when the tide rises and falls, and there is a home scar to which the animals return (Cook, 1969). The egg masses consist of cylindrical yellow gelatinous masses deposited in crevices on the rocky shoreline.

S. normalis is widely distributed through the Indo-West Pacific.

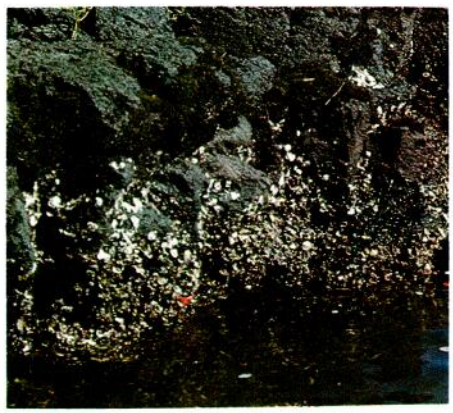
Williamia radiata (Pease, 1861b). Fig. 157 K, L. Length, 5 mm; diameter, 5 mm. *Shell:* conical, low, slightly broader posteriorly than anteriorly; apex subcentral, strongly recurved. *Sculpture:* with obsolete radiating ribs. *Color:* red-brown, with 12 to 15 narrow, light colored rays. *Interior:* smooth; internal muscle scar opening on right.

These limpets are subtidal, found under rocks on fringing reefs, and shells are common in sediments to depths of 30 m.

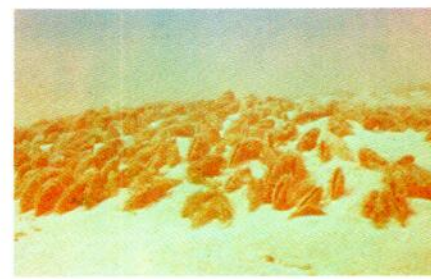
W. radiata was described from the Hawaiian Islands.

A

B

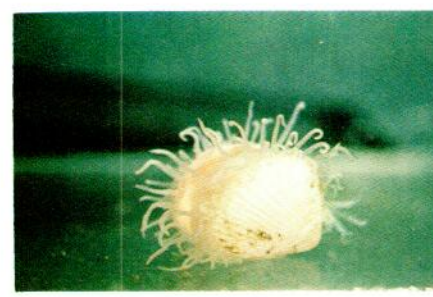


C



D

E



F

Figure 158.—Bivalve life styles. A. *Arca ventricosa* in a coral substrate. B. *Mirapecten mirificus*, the lower valve attached to the substrate. C. *Ostrea sandvicensis*, Hilo, Hawaii. D. *Pinna* bed at a depth of about 30 m. E. *Isognomon californicum* attached by byssal threads on a rock in the intertidal zone. F. *Lima* sp. with tentacles extruding from the shell. (A, B, and F courtesy O. Schoenberg; C. courtesy H. Sakuda; D. courtesy J. Maciolek.)

Class BIVALVIA

Plasticity of molluscan form is perhaps nowhere better expressed than in the Bivalvia, known also at various times in the past as the Acephala, Pelecypoda, and Lamellibranchia. In these mollusks the body is compressed between two mantle flaps which secrete a right and left shell valve hinged at the dorsal line. There is no definable head or radula. Instead, the mantle cavity is enlarged, accommodating highly developed gills which serve not only in respiration but also in food gathering and sorting, and, in some forms, as a brood chamber (Fig. 178 A). Sensory cells are concentrated at the edge of the mantle where light sensitive structures such as the "eyes" of pectens and tactile structures are found.

Although Yonge (1949) has suggested that "of all marine animals the bivalves are the most perfectly adapted for life within soft substrata of sand and mud," bivalves are also highly successful as settlers on rocky shores and borers of rock and wood. In burrowing bivalves the shell is usually sleek and elongate, there are two adductor muscles used in opening and closing the shell valves, and the foot is elongate and muscular, serving as a digging organ. In bivalves which live on hard substrates or which bore into rock and wood, shell shape and sculpture are modified, there is often only a single adductor muscle, and the foot is reduced, secreting a byssus which attaches the animal to the substrate.

Classification within the class has undergone even more change with time than has the name of the class itself. The 19th century French malacologist Douvillé recognized three branches among the bivalves based on the mode of life, a "normal" or vagrant epifaunal group which lie free at or near the surface or burrow actively, deep burrowing bivalves, and boring bivalves. Another 19th century French malacologist, Paul Pelseneer, classified bivalves on the basis of gill type, distinguishing the Filibranchia, Eulamellibranchiata, and Pseudolamellibranchia in which the gills act as filtering structures from which food suspended in the water is strained; the Protobranchia (*Nucula*) with rather small gills which obtain their food directly from the substrate by siphons; and the Septibranchia (*Cuspidaria*) in which the ctenidia are fused and act as muscular pumps. Still another method of distinguishing groups within the Bivalvia is that based on the form of the muscles, monomyarians distinguished by a single posterior muscle, as in the pectens, dimyarians with anterior and posterior adductor muscles both present (Fig. 159), and so forth.

American malacologists have tended to utilize hinge structure in their classificatory schemes. In the Taxodonta (arks and glycymerids) there are a large number of small alternating teeth on the hinge (Fig. 159). In the Actinodonta the teeth are

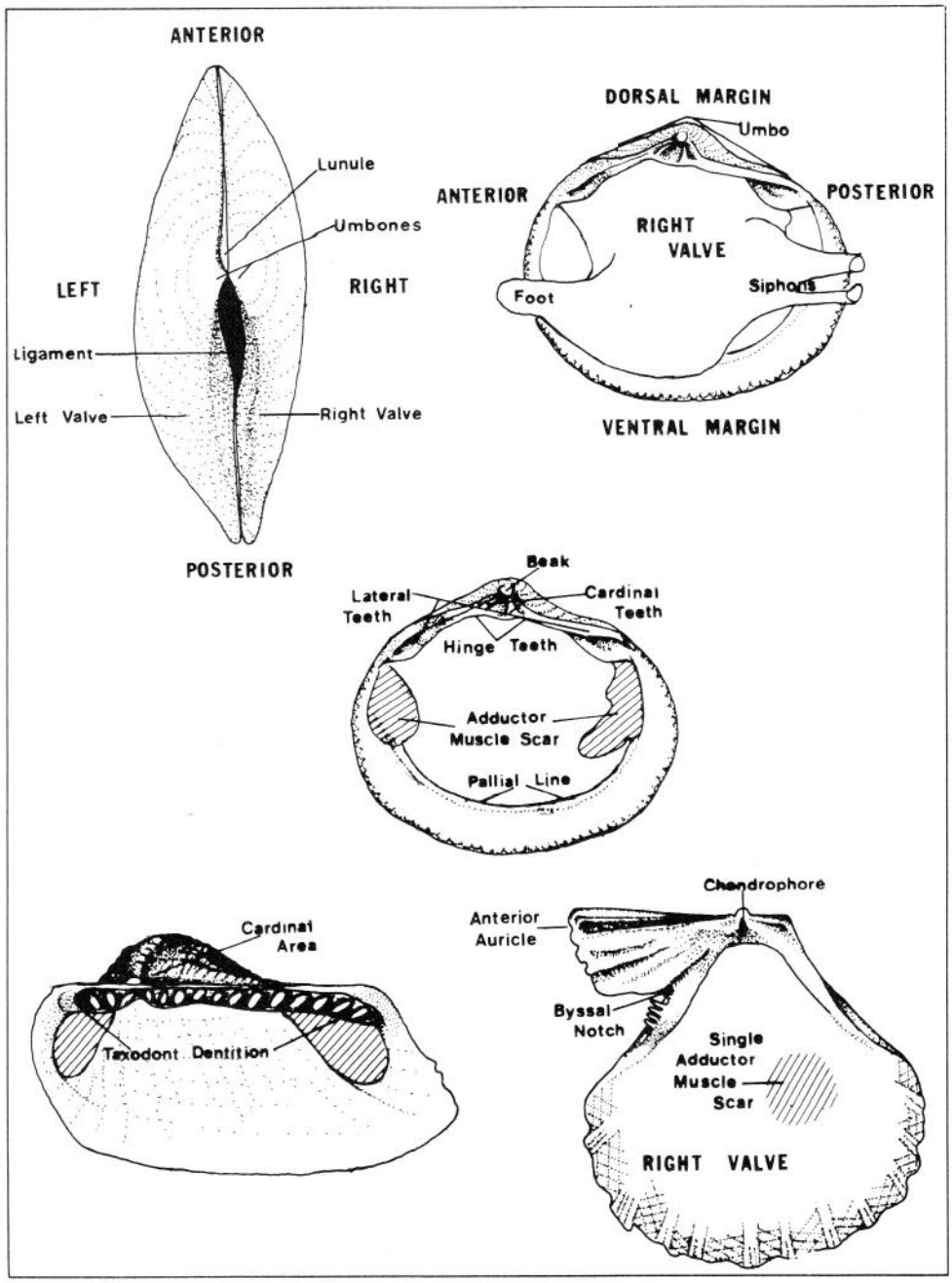


Figure 159.—Parts of bivalves. (By R. Kawamoto.)

elongate, radiating from the umbones. The teeth in the Heterodonta (for example, in the Lucinidae) are differentiated into cardinals and laterals (Fig. 159). The dentition of *Spondylus* and pectens (Fig. 159), where a single tooth fits into a socket, is termed isodont.

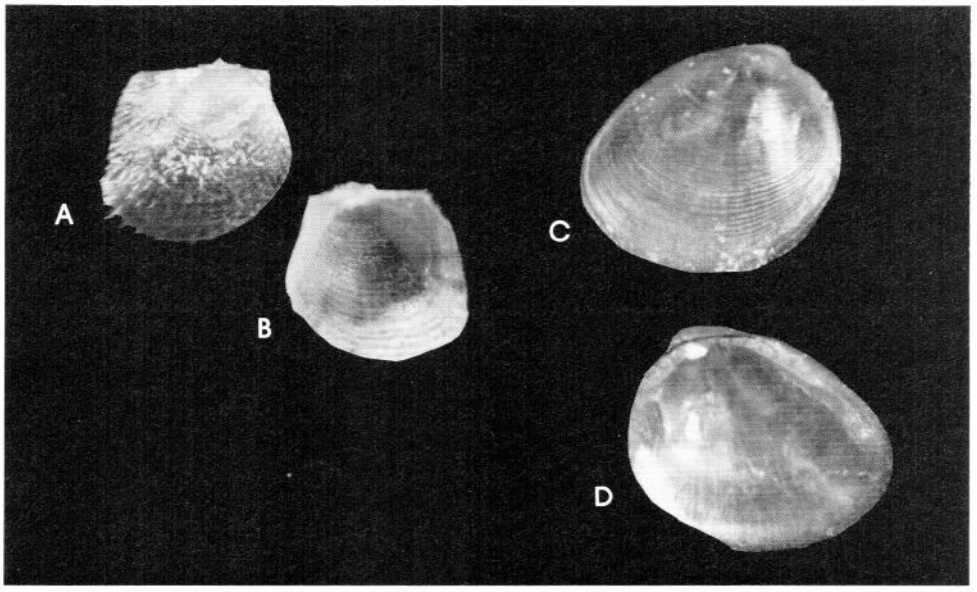


Figure 160.—**Nuculidae** and **Limopsidae.** A, B. *Limopsis waikikia*, length 2 mm. C, D. *Nucula hawaiensis*, length 2 mm.

Superfamily NUCULACEA

Family **Nuculidae**

The nut shells are small, equivalve bivalves, rounded to somewhat elongate in outline, smooth or marked by closely spaced, fine concentric lines, and inequilateral, with the beaks in the posterior half of each valve. The hinge teeth are in two series, anterior and posterior, separated by a chondrophore. The ligament is amphidetic, extending on either side of the beak. The exterior is porcelaneous and the interior nacreous. The pallial line is entire.

The Nuculidae are thought to be among the most primitive of living bivalves; among the features of their anatomy indicating their archaic origin are their long movable palps with tentaclelike structures which protrude from the shell and gather food from the sandy, silty deposits in which they live. The mantle margins are free and no siphons are developed. These bivalves burrow by means of the foot which projects from the antero-ventral part of the shell. Most species in the family are cold-water forms and tropical species are apt to occur in deep water.

Nucula hawaiensis Pilsbry, 1921. Fig. 160 C, D. Height, 2.8 mm; length, 2.2 mm. *Shell:* solid; beaks conspicuously behind the midline; obliquely oval in outline; smooth; white. *Margins:* anterior margin short, broadly rounded; posterior end produced and gently rounded; dorsal and ventral margins equally curved; margins finely denticulate. *Hinge:* eleven teeth on the posterior margin of the left valve, ten on the right valve; four teeth on the anterior margin of each valve. *Sculpture:* smooth on the umbonal region; microscopic fine, concentric lines of growth toward the ventral margin. *Color:* white.

These bivalves are occasionally found in the algal-sand mat of tide pools but are more common in sediments at depths of from 10 to 50 m.

N. hawaiensis was described from the Hawaiian Islands.

Superfamily ARCACEA

Shells of the Arcacea are distinguished by their taxodont dentition, numerous, subequal teeth along the hinge plate, and by separated beaks which expose the cardinal area. There are three families, the Arcidae with elliptical shells and a straight hinge, the Limopsidae with elongate-oval shells and a curved hinge, and the Glycymerididae with orbicular shells and a curved hinge. The group is an ancient one, exhibiting little specialization, and most species are epifaunal suspension feeders.

Family **Arcidae**

Ark shells are solid, usually inequivalve, and inequilateral with the beaks normally anterior to the midline. The sculpture is of prominent radial ribs and concentric threads and a fibrous or hairy periostracum usually covers the shell. The hinge line is long, with the ligament distributed in pits or grooves above it. There are two muscle scars which are equal in size. The pallial line is entire.

Arks occur in a variety of environments throughout the world. In Hawaiian waters the nestling or boring Arcinae are represented in shallow water, and the Anadarinae are found in deep water and as fossils.

The fossil record indicates that arks were much more common in shallow waters around the Hawaiian Island chain during the Pleistocene than they are today. Valves of *Arca ventricosa* are abundant in emerged reefs of the 95 foot Kaena stand of the sea at Barbers Point, Oahu. Fossil shells of the only Hawaiian representative of a burrowing ark, *Anadara, A. antiquata* Linnaeus, 1758 (Synonyms: *A. vetula* Dall, Bartsch, and Rehder, 1938; *A. hankeyana* Reeve, Ostergaard, 1928) are also abundant as Pleistocene fossils.

The genera of Hawaiian arks may be keyed as follows:

1. Muscle scars not elevated 2
   Muscle scars elevated ..... *Barbatia (Acar)*

2. (1) Rectangular or alate, strongly winged, with a prominent umbonal angle 3
   Semiglobose, inflated, not strongly winged and without a prominent umbonal angle 4

3. With a strong ventral gape; hinge line straight ..... *Arca*
   Ventral margin not strongly gaping; hinge line curved ..... *Bentharca*

4. Teeth continuous or nearly so on the hinge line 5
   With a distinct edentulous gap on hinge line ..... *Bathyarca*

5. Fine-ribbed and decussated; periostracum profuse ..... *Barbatia*

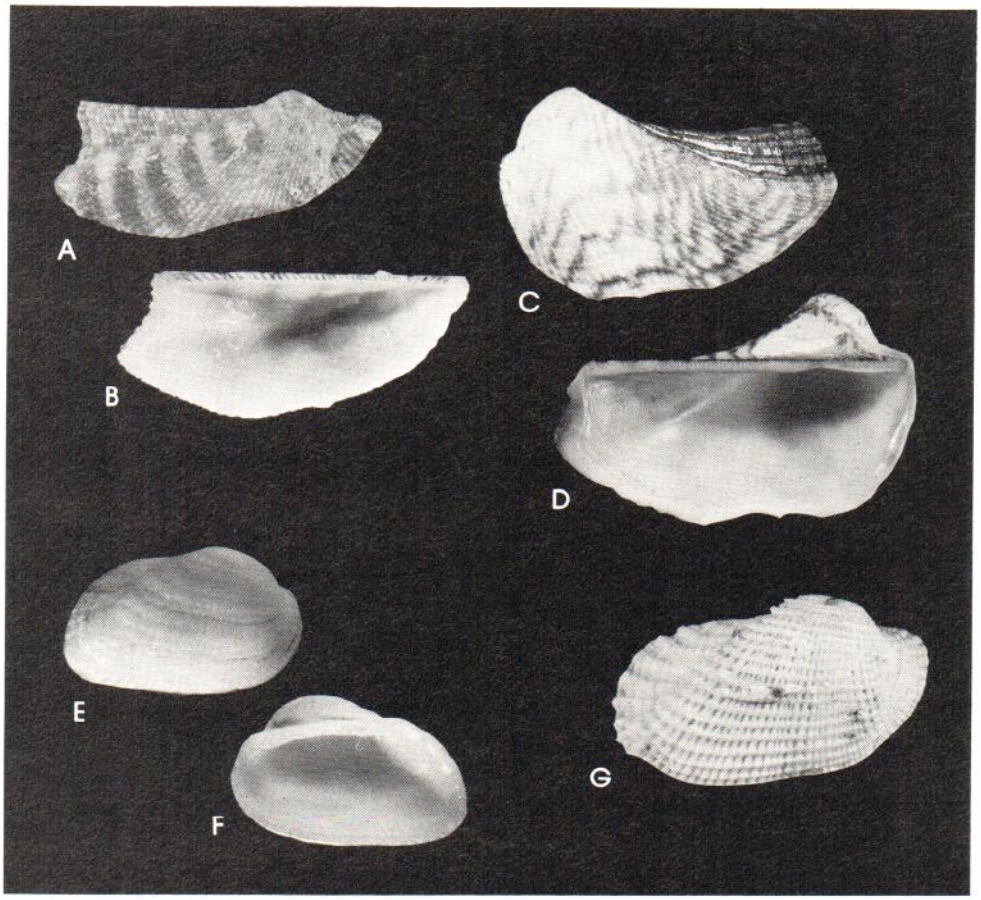


Figure 161.—**Arcidae.** A, B. *Arca kauaia,* length 14 mm. C, D. *A. ventricosa,* length 57 mm. E - G. *Barbatia divaricata,* length 28 mm.

Subfamily **Arcinae**

These arks are nestling or boring forms characterized by a byssal gape. The inner margin of the shell is not crenulate and the hinge line is as long as the shell. Noah's ark (*Arca noae,* Linnaeus, 1758) is the type species of the genus; it has a wide byssal gape and irregular radial sculpture. In *Barbatia* there is a narrower ligamentary area, the sculpture is cancellate, and the hairy periostracum evenly distributed.

Arca kauaia (Dall, Bartsch, and Rehder, 1938). Fig. 161 A, B. (Synonym: *Navicula mauia* Dall, Bartsch, and Rehder, 1938.) Height, 6 mm; length, 14 mm; diameter, 7 mm. *Shell:* solid, rectangular, equivalve; beaks moderately projecting; with radiating ribs and concentric lamellae; pale yellow maculated with red-brown. *Margins:* junction of anterior dorsal edge and lateral edge forming an acute angle; ventral margin contracted. *Hinge:* almost straight, with 32 to 40 teeth diminishing in size from the outside inward. *Sculpture:* strongly developed radiating ribs crossed by concentric lamellae forming nodules and imbricate scales at junctions with ribs; central portion of

shell with 26 to 32 ribs. *Color:* yellow with brown spots and blotches; interior white washed with red-brown.

This species occurs at depths of 50 m.

Although Dall, Bartsch, and Rehder (1938) distinguish two species, a single variable species is recognized here, the number of ribs and teeth on the valves increasing with increasing size. A Japanese subspecies, *A. mauia takii* Hatai, Niino, and Kotaka 1952, is recorded from Hachiojo-jima, Japan (Okutani, 1963). The narrow anterior border in *A. kauaia* distinguishes it from the widespread Indo-West Pacific species *A. navicularis* Bruguière, 1789.

Arca ventricosa Lamarck, 1819. Figs. 158 A; 161 C, D. (Synonyms: *Arca truncata* Reeve, Ostergaard, 1928; *A. fuscomarginata* Dunker, Mansfield, 1935.) Height, 30 mm; length, 57 mm; diameter, 32 mm. *Shell:* solid, heavy; ventral margin widely gaping; with radiating ribs crossed by concentric threads; flesh stained with brown. *Margins:* anterior margin forming a right angle at its junction with the hinge line and then curving gently toward the ventral margin; ventral margin sinuous; posterior margin produced as a feeble beak. *Hinge:* hinge line straight; with 90 or more teeth increasing in size from the center outwardly. *Sculpture:* fine radiating ridges which are nodular where they are crossed by concentric threads. *Color:* flesh stained with brown and with radiating lines of brown; posterior portion dark brown; interior blue-white to dark brown.

This ark is found at depths of about 10 m firmly attached by the byssus in coral off the fronts of fringing reefs; it is a commonly occurring species on nearly every reef at Pearl and Hermes Reef (Galtsoff, 1933), and on Midway. Valves are uncommon in beach drift on beaches of the windward islands. Ostergaard (1928) reports it as abundant in raised fossil reefs around Oahu.

A. ventricosa occurs throughout the Indo-West Pacific.

Barbatia alia (Dall, Bartsch, and Rehder, 1938). Fig. 162 K, L. Height, 3 mm; length, 5 mm; diameter, 2 mm. *Shell:* ovate, slightly inflated and convex; beaks moderately projecting; with fine radiating riblets; white. *Margins:* anterior lateral edge and posterior lateral edge joining dorsal edge in obtuse angles; ventral margin somewhat contracted in middle; all margins scalloped. *Hinge:* ligamental area moderately broad, posterior with four grooves; hinge narrow in middle, with about 23 teeth. *Sculpture:* threadlike radiating ribs, some bifurcating at base, cancellated by concentric threads; about five ribs on posterior margin developed as cords. *Color:* white; periostracum thin, brown.

These bivalves are rarely found at depths of 150 to 300 m.

B. alia was described from the Hawaiian Islands and has also been recorded from the Kermadec Islands (Powell, 1961). It is distinguished from *B. rectangula* by its smaller size and weaker sculpture.

Barbatia decussata (Sowerby, 1823). Fig. 162 G, H. (Synonyms: *Arca candida* Gmelin, Bryan, 1915; *A. hawaiiensis* Ostergaard, 1928 (in part), *nomen nudum; Barbatia oahua* Dall, Bartsch, and Rehder, 1938.) Height, 35 mm; length, 62 mm; diameter, 24 mm. *Shell:* oval; beaks projecting slightly above dorsal margin; with

nodulose radiating ribs; white. *Margins:* anterior and posterior margins evenly curved; ventral edge slightly contracted at the byssal gape. *Hinge:* narrow in the center and widening toward the extremities, with about 55 teeth. *Sculpture:* moderately strong radiating ribs made nodulose by the concentric sculpture. *Color:* white; interior porcelaneous; periostracum dark brown.

These bivalves were formerly common in Kaneohe Bay, Oahu, at depths of 1 to 3 meters but are only occasionally found in the area today.

The Hawaiian shells appear to represent the widely distributed Indo-West Pacific species.

Barbatia (Acar) divaricata (Sowerby, 1833). Fig. 161 E-G. (Synonyms: *Arca reticulata* Gmelin, Ostergaard, 1928; *Acar hawaiensis* Dall, Bartsch, and Rehder, 1938; *A. laysana* Dall, Bartsch, and Rehder, 1938.) Height, 20 mm; length, 28 mm; diameter, 16 mm. *Shell:* rectangular equivalve; beaks projecting strongly above the dorsal margin; an oblique ridge radiating from umbo to junction of posterior and ventral margins; valves often distorted; with radiating ribs and concentric lamellae; white. *Margins:* dorsal margin slightly curved; posterior lateral margin slightly produced; ventral margin sinuous, gaping anteriorly, and with strong denticles. *Hinge:* ligamental area narrow; hinge with about 21 teeth, the outer teeth smaller than the rest. *Sculpture:* strong, elevated radiating ribs and concentric threads forming imbricated, tilelike elements; seven ribs on anterior lateral area, nine on posterior, and 36 in the center. *Color:* white tinged with buff; interior white. Valves often distorted.

These bivalves are found nestled in cracks and crevices on the undersurfaces of rocks on fringing reefs and in tide pools, and valves have been dredged from depths to 200 meters.

B. divaricata was described from the Tuamotus and is widely distributed in the Indo-West Pacific. Authors disagree on the name of this species, and it is variously referred to as *Arca plicata* Chemnitz, 1795 (see Lamy, 1907; Lynge, 1909) and *A. reticulata* Gmelin, 1791 (see Woodring, 1925). Because of their nestling habit, the valves of these arks are often variable in shape. The small size, inflated form, and lesser number of hinge teeth utilized by Dall, Bartsch, and Rehder (1938) to distinguish *B. laysana* fall well within the range of variability of a single species.

The group of species to which these arks belong is sometimes treated as a separate genus, *Acar*, because of the raised muscle scars.

Barbatia lima (Reeve, 1844). Fig. 162 A, B. (Synonyms: *Arca granulata* Philippi, 1847; *Barbatia hawaia* Dall, Bartsch, and Rehder, 1938.) Height, 14 mm; length, 27 mm; diameter, 10 mm. *Shell:* ovate-elongate; beaks only slightly projecting; with radiating ribs and concentric threads; white. *Margins:* anterior border curved; posterior margin oblique and curved; ventral border constricted centrally; anterior and ventral margins finely denticulate. *Hinge:* narrow in the middle and tapering at each end, with 44 teeth. *Sculpture:* radiating ribs and concentric threads nodulose at the junctions; posterior lateral margin with five strong cords, central portion with less noticeable cords. *Color:* exterior white; interior porcelaneous; periostracum dark wood-brown.

These bivalves occur in silty sand in tide pools.

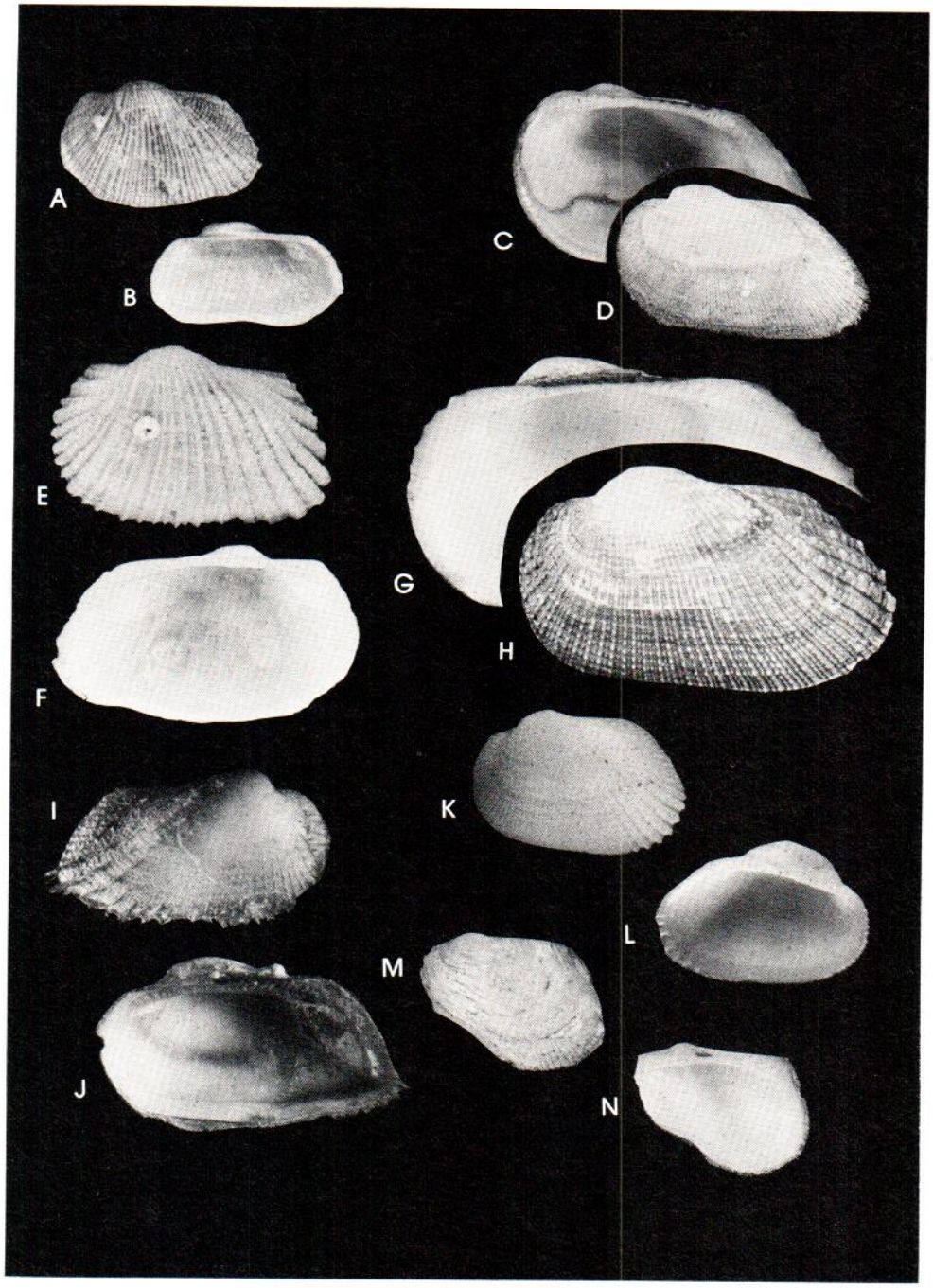


Figure 162.—**Arcidae.** A, B. *Barbatia lima,* length 27 mm. C, D. *B. tenella,* length 27 mm. E, F. *B. rectangula,* length 15 mm. G, H. *B. decussata,* length 62 mm. I, J. *B. nuttingi,* length 10 mm. K, L. *B. alia,* length 5 mm. M, N. *Bentharca asperula,* length 11 mm.

B. lima is widely distributed in the Indo-West Pacific from the Gulf of Aden to Hawaii (Lynge, 1909). It is distinguished from *B. decussata* by its smaller size and strong ribs on the posterior lateral margin.

Barbatia molokaia Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 9 mm; length, 18 mm; diameter, 6 mm. *Shell:* elongate-oval; with radiating ribs and concentric threads; flesh-colored. *Margins:* anterior evenly rounded and joining dorsal line in a right angle; posterior edge produced; ventral margin slightly constricted. *Hinge:* gently curved on inner border, with about 35 teeth. *Sculpture:* radiating ribs and concentric threads which are nodulose at the junctions; anterior lateral area with eight ribs, posterior lateral area with five ribs separated by deep, broad channels; central area with 55 slender threads. *Color:* exterior flesh; interior porcelaneous white; periostracum thin, spotted and flecked with brown.

These arks have been dredged at depths of about 48 m.

B. molokaia was described from the Hawaiian Islands. It is a distinctive deep-water species distinguished by its mottled periostracum.

Barbatia nuttingi (Dall, Bartsch, and Rehder, 1938). Fig. 162 I, J. (Synonym: *Calloarca maunaluana* Dall, Bartsch, and Rehder, 1938.) Height, 4 mm; length, 7 mm; diameter, 5 mm. *Shell:* suboval, inflated; beaks stout and moderately projecting; with fine radiating ribs; flesh colored, or brown and white. *Margins:* anterior edge well rounded; posterior edge curved but slightly produced at junction with ventral edge; ventral margin straight. *Hinge:* ligamental area moderately broad, with fine grooves; hinge narrowest at junction of anterior and posterior parts and edentulous in the center, with 15 to 20 teeth. *Sculpture:* fine radiating ribs and concentric threads nodulose at the junctions. *Color:* exterior flesh to brown; interior porcelaneous white; periostracum thin.

This is a commonly occurring ark, found nestled on the undersurfaces of rocks and coral in tide pools, shoreward of fringing reefs, and to depths of 48 m. Byssal attachment is weak.

B. nuttingi was described from the Hawaiian Islands. The shells are distinguished from those of *B. parva* (Sowerby, 1833) by their smaller size (the type lot of *B. parva* ranges from 9 - 12 mm in length) and the edentulous gap in the hinge.

Barbatia rectangula (Dall, Bartsch, and Rehder, 1938). Fig. 162 E, F. Height, 10 mm; length, 15 mm; diameter, 6 mm. *Shell:* ovate, slightly inflated and convex; beaks projecting only slightly; with imbricated radiating ribs; white. *Margins:* anterior edge rounded; posterior margin sloping, slightly oblique; ventral margin constricted; all margins scalloped. *Hinge:* ligamental area moderately wide, posterior area with seven grooves; hinge narrow in the middle and widening outwardly, completely denticulated with 20 to 40 teeth. *Sculpture:* imbricated radial ribs, some bifurcated at the base. *Color:* exterior and interior white; periostracum thin, translucent, pale brown.

These bivalves occur at depths of from 25 to 29 m.

B. rectangula was described from the Hawaiian Islands but may also occur in the Gulf of Siam (Lynge, 1909 as *Arca dichotoma* var *gratiosa*). The valves are distinguished from those of *B. alia* by their more prominent sculpture, lesser convexity, and larger size.

Barbatia tenella Reeve, 1844. Fig. 162 C, D. (Synonym: *Calloarca hua* Dall, Bartsch, and Rehder, 1938.) Height, 15 mm; length, 27 mm; diameter, 11 mm. *Shell:* oval, inflated and thin-shelled; with fine radiating threads; cream. *Margins:* anterior edge gently curved; posterior margin slightly oblique; ventral margin straight. *Hinge:* ligamental area narrow, marked posteriorly by four grooves; hinge narrow, widening toward the edges; anterior with five or six teeth, posterior with 29 or 30 teeth, and with a toothless gap between the anterior and posterior parts. *Sculpture:* fine radiating ribs which increase in size ventrally and in numbers by bifurcating. *Color:* white or cream with a thin, translucent periostracum which develops strong, brown, hairlike projections in the interradial spaces.

Valves are fairly common in dredge hauls at depths of 30 m, and specimens are occasionally found in shallow water on fringing reefs.

This species occurs throughout the Indo-West Pacific, in the Laccadive and Maldive archipelagoes, Djibouti, Bourbon, Madagascar, and the Philippines (Lynge, 1909), and in the Tuamotu (Morrison, 1954b) and Marshall Islands.

Additional Records

Barbatia hiloa Dall, Bartsch, and Rehder, 1938, was described from a single specimen from Keaukaha, Hawaii, but has not been recognized since. The broad ligamental area which characterizes the valve allies it with *B. hendersoni* Dall, Bartsch, and Rehder, 1938, described from fossil or subfossil shells found at Pearl Harbor, but the valves of *B. hendersoni* are much larger (length, 82 mm in *B. hendersoni*, 30 mm in *B. hiloa*).

Subfamily **Anadarinae**

Arks in this group have no byssal gape and the hinge line is somewhat arched. They are burrowers. The two species in the group in Hawaiian waters are deep-water forms. In *Bathyarca* (type, *Arca petunculoides* Scacchi, 1833) the shells are small and thin or with fine radial ribs. The shells of *Bentharca* (type, *Macrodon asperula* Dall, 1881, o.d.) are similar but the extremities are quadrate.

Bathyarca pisum Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 3 mm; length, 4 mm; diameter, 3 mm. *Shell:* semiglobose; thin, inflated; beaks projecting moderately above the dorsal margin; with fine radiating ribs and concentric threads; cream. *Margins:* anterior lateral edge joins dorsal in a right angle and then curves; posterior lateral edge obtuse, ventrally curved; ventral edge inflated. *Hinge:* ligament very narrow, posterior portion with two grooves; hinge narrow, with an edentulous gap; posterior portion with five oblique, denticulated teeth, anterior with five shorter teeth. *Sculpture:* umbonal area with radial and concentric striations only, the striations becoming threadlike ventrally. *Color:* cream; periostracum thin, translucent, straw-colored to golden brown.

Specimens of *B. pisum* were dredged by the *Albatross* at depths of more than 100 m.

This species was described from the Hawaiian Islands.

Bentharca asperula (Dall, 1881). Fig. 162 M, N. (Synonyms: *Bentharca hawaiensis* Dall, Bartsch, and Rehder, 1938; *B. kauaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 7 mm; length, 11 mm. *Shell:* wedge-shaped; right valve smaller than left; beaks projecting but slightly above dorsal margin; with nodulose radiating ribs and concentric threads; cream-yellow. *Margins:* anterior lateral edge joining dorsal margin at a right angle and curving gently to ventral margin; posterior lateral edge almost a straight line; ventral edge slightly constricted medially. *Hinge:* ligamental area broad with six oblique grooves; hinge rather broad, narrowed in the middle, anterior area with eight, posterior with six, well-developed teeth. *Sculpture:* concentric cords becoming lamellarlike and crossed by radiating riblets which gradually increase in strength, forming nodules where they cross cords. *Color:* cream-yellow; interior milk-white; periostracum golden brown, with a beardlike fringe on the anterior ventral margin.

These bivalves have been dredged at depths of from 20 to 100 m.

This species is regarded as a variable and widely distributed deep-water form occurring in the North Atlantic and Pacific Oceans; the Hawaiian shells fall well within the range of variability of the species as presently recognized by Knudsen (1967). In the Indian Ocean these arks are strongly attached by byssal threads to hexactinellid sponges (Knudsen, 1967).

Superfamily LIMOPSACEA

Family **Limopsidae**

The shells of members of this family are small, compressed, and suborbicular; they are equivalve and inequilateral, the beaks anterior to the midline. There is an external, triangular ligament pit, and the hinge line is curved, with a series of more or less oblique teeth. The sculpture consists of conspicuous radial striae. A dense, long and silky periostracum covers the shells in life.

Limopsis waikikia Dall, Bartsch, and Rehder, 1938. Fig. 160 A, B. Height, 2 mm; length, 2 mm; diameter, 1 mm. *Shell:* subglobular, oblique; an obscure ridge extending from the beaks to the junction of the posterior lateral margin; with strong concentric cords crossing radiating riblets; golden yellow. *Hinge:* ligament small, triangular, with the apex of the triangle immediately below the beak; hinge moderately broad with fine, vertical teeth. *Sculpture:* fine radiating ribs separated by interspaces of greater diameter and crossed by stronger, closely spaced, well-rounded cords. *Color:* exterior golden yellow, interior pale brown; periostracum thin, golden yellow, forming hairlike filaments at the junctions of the radiating ribs and concentric cords.

Valves are common in sediments at depths of from 4 to 20 m.

L. waikikia was described from the Hawaiian Islands.

Family **Glycymerididae**

The glycymeridids are thick-shelled bivalves which burrow just beneath the surface of the substrate. The shells are usually equivalve and equilateral, porcelaneous and solid, and sculptured by strong radiating cords. The ligament is external and the

teeth on the arched hinge plate are chevron-shaped or bent. There are two muscle scars; the pallial line is entire.

Although many members of this family are common elsewhere in tropical shallow, subtidal waters and their shells "may occur in millions on ocean beaches" along the Great Barrier Reef (Rippingale and McMichael, 1961), the Hawaiian glycymeridids occur from moderate depths to deep water and their shells are rarely seen on the beaches.

Living members of the Glycymerididae are divided into two large groups of species, the more ancient and more widely distributed geographically typified by *Glycymeris sensu stricto*, the other by *Tucetona* which is apparently the only one represented among the islands of the central Pacific (Nicol, 1956).

Glycymeris arcodentiens (Dall, 1895). Fig. 163 A, B. (Synonym: *Glycymeris mauia* Dall, Bartsch and Rehder, 1938.) Height, 19 mm; length, 19 mm; diameter, 8 mm. *Shell:* circular, inflated; with high rounded radiating ribs crossed by concentric lamellae; interior margin fluted, ribs not projecting beyond margin; yellow-white blotched with pale brown. *Hinge:* ligament with three broad chevrons on each side; hinge rather broad, evenly arcuate, with 9 teeth anteriorly, 11 posteriorly. *Sculpture:* 20 broad, rounded radiating cords; interspaces of lesser diameter and shallow; ribs and interspaces crossed by numerous slender lamellae, the space between the lamellae of greater diameter and finely striate. *Color:* yellow-white, inconspicuously blotched with pale brown; interior white.

These bivalves occur at depths of 30 to 40 m.

G. arcodentiens was described from the Hawaiian Islands.

Glycymeris diomedea Dall, Bartsch, and Rehder, 1938. Fig. 163 E, F. (Synonym: *Glycymeris oahua* Dall, Bartsch, and Rehder, 1938.) Height, 16 mm; length, 16 mm. *Shell:* subcircular, thick and inflated; barely inequilateral with the beaks anterior to the midline; with flat, straight-sided, scaly ribs and strong, lamellose concentric threads; margins conspicuously scalloped with the ribs projecting beyond the edge of the shell; white, blotched and spotted with chestnut brown. *Hinge:* ligament narrow with three chevrons; hinge moderately arcuate, anterior with nine teeth, posterior with 11 teeth, the inner four smaller than the rest. *Sculpture:* 23 to 25 elevated, flattened, straight-sided ribs which are medially grooved basally; ribs separated by interspaces of lesser diameter; concentric sculpture of strong lamellose cords separated by finely striated spaces of greater diameter, the cords strongest on the ribs where they appear like overhanging tiles. *Color:* exterior profusely blotched and spotted with bright chestnut brown; interior white with a buff tinge, ventral margin pale brown.

Specimens of *G. diomedea* have been dredged at depths of 200 to 750 m.

This species was described from the Hawaiian Islands.

Glycymeris molokaia Dall, Bartsch and Rehder, 1938. Fig. 163 G, H. Height, 17 mm; length, 17 mm; diameter, 12 mm. *Shell:* subcircular; beaks anterior to the midline; with nodulose radiating ribs; anterior margins decidedly scalloped; yellow-white. *Hinge:* ligament narrow with three distinct folds posteriorly; hinge more arched posteriorly than anteriorly, 10 teeth anteriorly, 12 teeth posteriorly. *Sculpture:* 29 strongly elevated radial ribs, the ribs a little wider than the interspaces and strongly

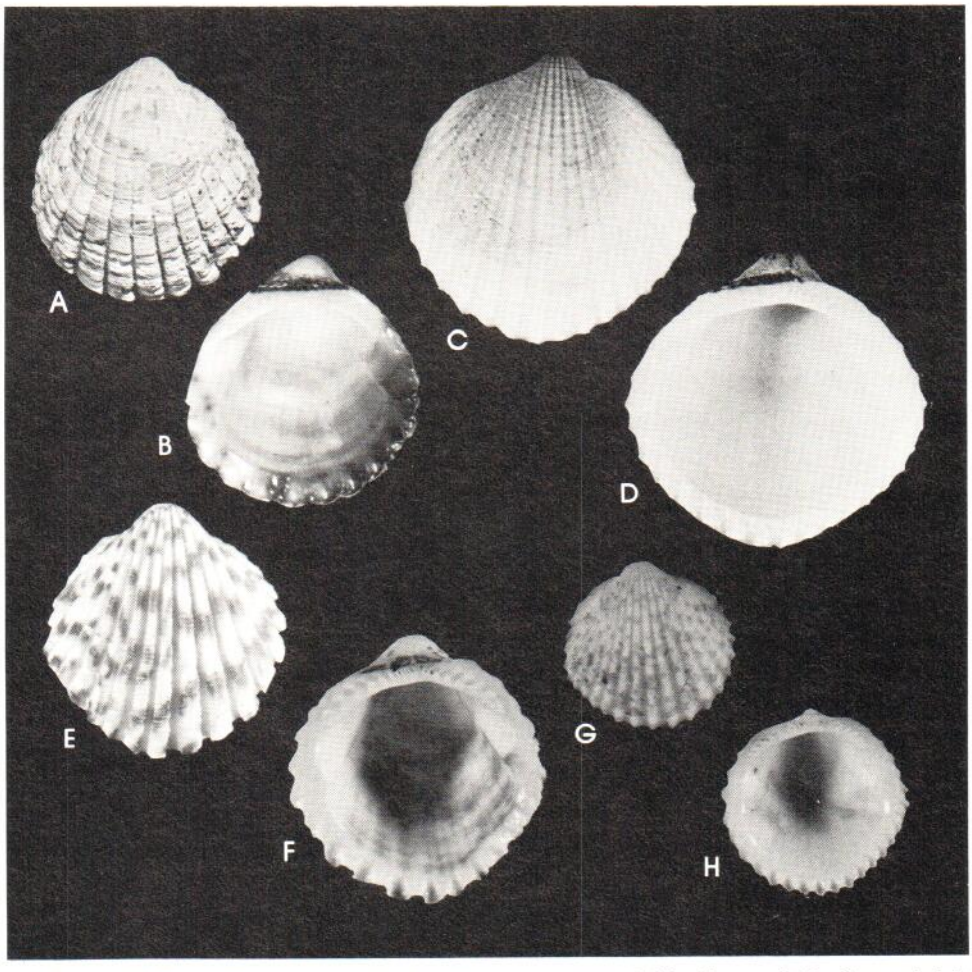


Figure 163.—**Glycymerididae.** A, B. *Glycymeris arcodentiens*, height 19 mm. C, D. *G. nux*, height 19 mm. E, F. *G. diomedea*, height 16 mm. G, H. *G. molokaia*, height 17 mm.

scalloping the margin; concentric sculpture of lamellae which render the ribs nodulose. *Color:* yellow-white.

These bivalves are uncommon, dredged at depths of about 60 m.

G. molokaia was described from the Hawaiian Islands. The valves are distinguished from those of *G. nux* by their almost circular outline.

Glycymeris nux Dall, Bartsch, and Rehder, 1938. Fig. 163 C, D. Height, 18 mm; length, 19 mm; diameter, 16 mm. *Shell:* subquadrate; beaks anterior to the midline; with nodulose radiating ribs; anterior and posterior margins feebly scalloped; pale yellow with brown concentric markings. *Hinge:* ligament narrow with five grooves posteriorly; hinge evenly arcuate, 10 or 11 teeth anteriorly, 13 posteriorly; the outer teeth smaller. *Sculpture:* 23 strong, rounded radial ribs, the central rib running somewhat diagonally, and the interspaces of equal diameter; concentric sculpture of

heavy cords, which render the ribs tubercled, and of striae in the interspaces. *Color:* exterior pale yellow with brown concentric markings; interior white.

This species is fairly common at depths of about 20 m.

G. nux was described from the Hawaiian Islands.

Additional Records

Two additional species of *Glycymeris* were described by Dall, Bartsch, and Rehder (1938) from material dredged by the *Albatross*. *G. kauaia*, described from a single valve dredged from 43 to 52 m, resembles *G. nux* in shape but the sculpture is more scabrous than nodular and the intercostal spaces are deep as in *G. diomedea*. *G. kona*, described from valves dredged at depths of 35 to 90 m, has subcircular, thin, white valves. The margins are distinctly scalloped as in *G. arcodentiens* but the sculpture is neither nodular nor scabrous.

Superfamily MYTILACEA

Family **Mytilidae**

The mussels are well-known sedentary bivalves, thousands of which settle on benches along the shoreline, on rocks and piers, in tropical and temperate waters. Several members of the family are also adapted to other habitats: burrowing in coral, nesting in soft substrata, and some are commensal in tests of ascidians. The sedentary mussels (*Brachidontes* and *Septifer*) are slipper-shaped and attached to the substrate by a byssus; the borers (*Botula, Gregariella, Lithophaga,* and *Terua*) are cylindrical or arcuate; the nest-builders (*Amygdalum* and *Modiolus*) are spatulate and thin-shelled; and the commensals (*Musculus*) are oval and thin-shelled.

Mytilid shells are equivalve, generally inequilateral, with the beaks anterior to the midline and directed inward. The ligament is either external or internal, elongate and deep-seated; the hinge line is without teeth although there are sometimes toothlike crenulations present. There are two unequal muscle scars, the anterior adductor smaller than the posterior. The pallial line is entire.

The Hawaiian mytilid genera may be keyed as follows:

1. Thin-shelled, fragile, bean-shaped, cylindrical or spatulate 2
   Shell moderately thick, slipper-shaped to subquadrangular 5

2. (1) Bean-shaped, smooth or with radiating ribs 4
   Cylindrical or spatulate 3

3. (2) Cylindrical with wrinklelike striations, tan to brown ..... *Lithophaga*
   Spatulate, smooth, white or white with green ..... *Amygdalum*

4. (2) Bean-shaped with fine radiating riblets ..... *Musculus*
   Bean-shaped, smooth or with concentric striae ..... *Terua*

5. (1) Slipper-shaped or triangular with radiating riblets 6
   Subquadrate or rhomboidal, smooth or with steplike notches 7

6. (6) Triangular with radial riblets and concentric threads; cream with red-brown ..... *Septifer*
Slipper-shaped with radial riblets and concentric threads; brown ..... *Brachidontes*

7. (5) Subquadrate with steplike notches; pale brown ..... *Botula*
Rhomboidal, smooth; red or yellow ..... *Modiolus*

Amygdalum newcombi (Dall, Bartsch, and Rehder, 1938). Fig. 164 A, B. Height, 17 mm; length, 9 mm; diameter, 5 mm. *Shell:* ovate, inflated, thin; the beaks posterior to the midline; with faint growth lines and striations; translucent and glassy. *Ligament:* extending about one-third the length of the shell posterior to the midline. *Sculpture:* with feeble growth lines and radiating striae. *Color:* interior and exterior translucent and glassy.

These bivalves occur at depths of 40 to 50 m.

A. newcombi was described from the Hawaiian Islands, but it resembles *A. watsoni* (Smith, 1885) dredged by the *Challenger* in the Philippines.

Amygdalum peasei (Newcomb, 1870). Fig. 164 C, D. Height, 37 mm; length, 19 mm; diameter, 13 mm. *Shell:* elongate-ovate, moderately inflated, thin; beaks posterior to the midline and projecting slightly; smooth and polished; cream-white variegated with brown posteriorly. *Ligament:* extending about one-half of the length of the shell posterior to the midline. *Sculpture:* growth lines and fine radiating striations. *Color:* exterior cream-white variegated on the posterior dorsal portion with a network of brown reticulations; interior blue-white; periostracum thin, yellow.

A. peasei occurs at depths of from 1 to 10 m. These bivalves live in nests of rather loosely woven byssal threads to which are attached pieces of shells, foraminiferans, and bits of coral.

This species was described from the Hawaiian Islands. It resembles the type species of the genus (*A. dendriticum* Megerle von Mühlfeld, 1811) which lives in the Caribbean. Similar mussels occur throughout the western Pacific but their relationship to the Hawaiian species is unresolved.

Botula silicula (Lamarck, 1819). Fig. 164 E, F. (Synonyms: *Botula hawaiensis* Dall, Bartsch and Rehder, 1938; *B. laysana* Dall, Bartsch and Rehder, 1938.) Height, 11 mm; length, 6 mm; diameter, 6 mm. *Shell:* subquadrate, convex, thin; umbones prominent, curved; with weak concentric growth lines; pale brown. *Hinge:* straight, edentulous. *Sculpture:* numerous concentric growth lines interrupted by deeper grooves marking growth stages, occasionally with microscopic radiating striae. *Color:* pale brown; periostracum glossy brown.

This mytilid is known in the Hawaiian Islands only from valves dredged at depths of 10 to 200 meters. Species of *Botula* are presumably rock borers which bore by mechanical means into soft, noncalcareous rock (Olsson, 1961).

Iredale (1939b) showed that *B. silicula* is an available name for the Indo-West Pacific species which is often reported as *B. cinnamomeus* Lamarck, 1819, a preoccupied name (Olsson, 1961).

The single subfossil valve dredged by the *Albatross* near Laysan Island and described as *B. laysana* (Dall, Bartsch and Rehder, 1938) differs from valves of *B.*

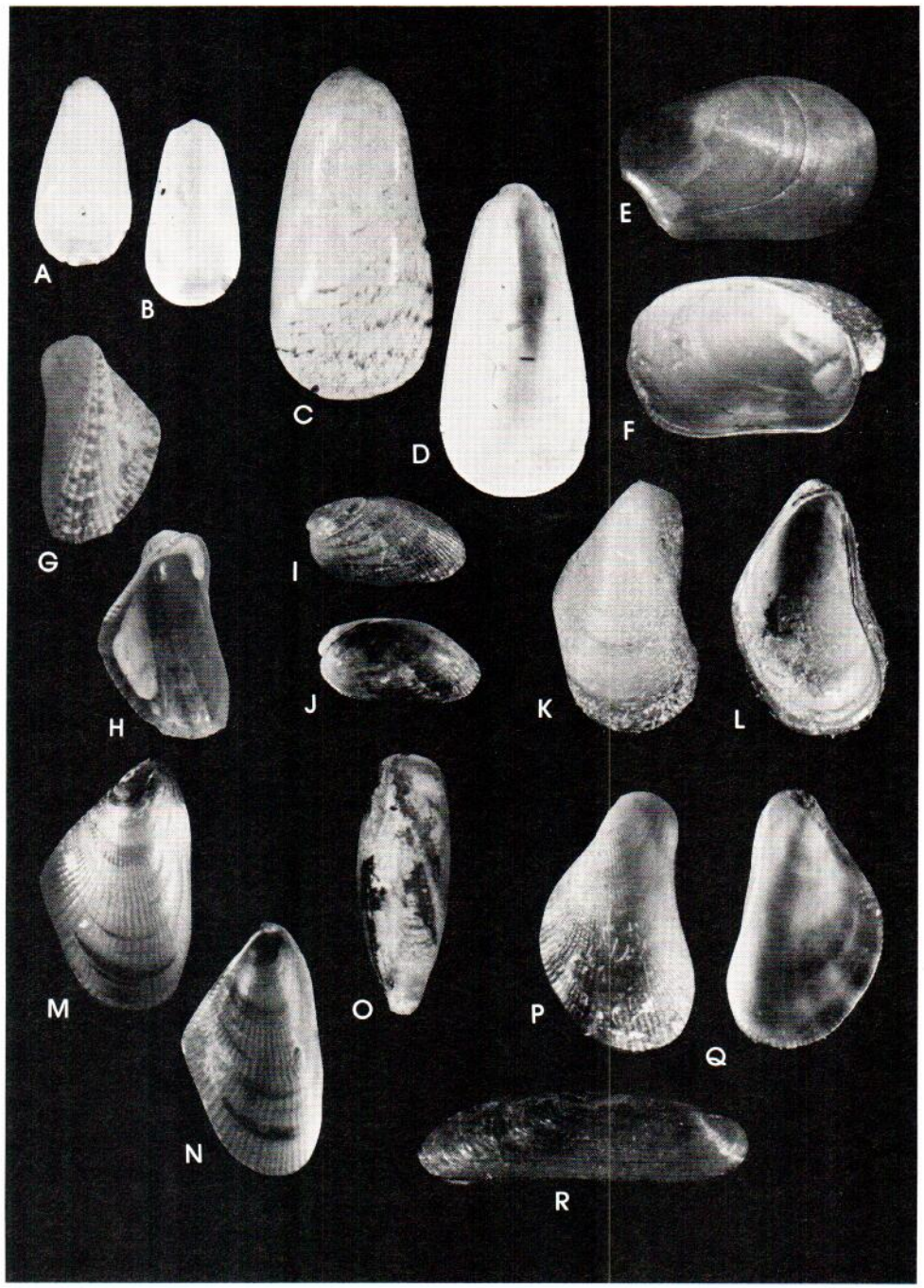


Figure 164.—**Mytilidae.** A, B. *Amygdalum newcombi*, height 17 mm. C, D. *A. peasei*, height 37 mm. E, F. *Botula silicula*, height 11 mm. G, H. *Septifer rudis*, height 13 mm. I, J. *Musculus aviarius*, height 11 mm. K, L. *Modiolus matris*, height 11 mm. M, N. *Brachidontes crebristriatus*, height 30 mm. O. *Lithophaga fasciola*, height 16 mm. P, Q. *Septifer bryanae*, height 12 mm. R. *Terua crypta*, height 4 mm.

silicula only in its slightly smaller size (height, 9.5 mm; length, 5.4 mm) and somewhat deeper grooves.

Brachidontes crebristriatus (Conrad, 1837). Fig. 164 M, N. (Synonym: *Mytilus crebristriatus* form *maritima* Pilsbry, 1921.) Height, 30 mm; length, 11.5 mm; diameter, 12 mm. *Shell:* slipper-shaped, moderately thin and inflated, inequivalve; beaks terminal; with radiating riblets; yellow to brown. *Margins:* ventral and dorsal margins parallel; posterior edge well-rounded; dorsal, posterior and ventral margins denticulated. *Sculpture:* numerous rounded, radiating riblets which increase by bifurcation, the interspaces subequal; riblets rendered finely nodulose by feebly developed concentric threads. *Color:* exterior dark brown; interior pale anteriorly and darkening to brown posteriorly; periostracum golden brown, shining, and concentrically banded with brown.

These mytilids are extremely abundant on limestone shorelines where they pave patches of solution benches at the 0 tide mark; they are found in lesser densities along basalt shores, and, indeed, are ubiquitous around the shorelines of the windward islands. The mussels are firmly attached to the substrate by a strong byssus, but when they are detached they can creep about on the narrow, fingerlike foot.

The shells of mussels occurring where there is freshwater outflow are generally larger, thinner, and less sculptured than those which are found in normally saline waters. Because Conrad's (1837) types were described from Pearl Harbor where there is considerable freshwater incursion, Pilsbry (1921) distinguished the smaller marine mytilids as form *maritima*. There appears to be little reason for distinguishing the forms on conchological grounds, as valves intermediate between the extremes are common.

Lithophaga fasciola Dall, Bartsch, and Rehder, 1938. Fig. 164 O. Height, 16 mm; length, 6 mm; diameter, 6 mm. *Shell:* cylindrical, thin, inflated; beaks posterior to the midline; with wrinklelike striations; brown. *Margins:* dorsal line straight, ventral convex. *Sculpture:* concentric growth lines and wrinklelike striations crossing growth lines at right angles. *Ligament:* extending from dorsal angle to anterior edge and forming an impression extending anteriorly under the beaks. *Color:* exterior brown, often with a calcareous coat; interior pale livid; periostracum thin, golden brown.

These bivalves bore in coral and have been collected at depths of from less than a meter to 100 meters. The lithophagids are not common, occurring only in about 1 percent of more than 100 coral heads examined in shallow water. Boring in *Lithophaga* is confined to calcareous rock and it has been suggested that the anterior glands may secrete an acid mucus. Byssal attachment is weak and the valves are little eroded.

L. fasciola was described from the Hawaiian Islands.

Lithophaga hawaia Dall, Bartsch and Rehder, 1938. (Synonym: *L. obesa* Philippi, Ostergaard, 1928.) The species was described from a specimen dredged at the entrance to Honolulu Harbor, Oahu, and distinguished from *L. fasciola* by its large size (60 mm). The authors noted that the type may have been a fossil. Examination of several specimens attributable to *L. hawaia* indicates that all are fossils. Because no living lithophagids greater than 25 mm in length have been found living in Hawaiian

waters, it would seem that the larger species no longer occurs here. Ostergaard (1928) noted that the larger form was abundant in a fossil reef in Hahaione Valley, Oahu, an occurrence which contrasts sharply with the relative rarity of lithophagids in corals in Hawaiian waters at the present time. Rehder and Ladd (1973) record *Lithophaga mucronata* Hanley from the Kure shelf at depths of 15-60 m.

Modiolus matris (Pilsbry, 1921). Fig. 164 K, L. Height, 11 mm; length, 6 mm; diameter, 6 mm. *Shell:* irregularly rhomboidal; thin; inflated; beaks posterior to the midline; smooth; red or yellow. *Margins:* anterior and basal edges concave; posterior and dorsal margins curving. *Ligament:* impressed as a groove and lying beneath a shelf formed by the anterior portion of the shell. *Sculpture:* prodissoconch finely granulose; later stages with numerous, closely crowded, concentric threads separated by striae. *Color:* exterior orange-brown to orange in live-collected shells, beachworn shells red and yellow; interior white; periostracum thin, horn-colored with numerous scattered hairs; byssus straw colored.

M. matris occurs at depths of from 5 to 8 m; beachworn specimens are sometimes common in drift.

This species was described from the Hawaiian Islands.

Musculus aviarius Dall, Bartsch, and Rehder, 1938. Fig. 164 I, J. (Synonyms: *Musculus oahua* Dall, Bartsch, and Rehder, 1938; *M. laysanus* Dall, Bartsch, and Rehder, 1938; *M. pailolus* Dall, Bartsch, and Rehder, 1938.) Height, 11 mm; length, 6 mm; diameter, 6 mm. *Shell:* bean-shaped, thin and inflated; beaks projecting moderately above the hinge line; green to yellow-white. *Margins:* dorsal line curving evenly from beak to posterior portion; posterior margin somewhat produced; anterior edge strongly curved; ventral margin straight. *Sculpture:* two sets of radiating riblets separated by a broad median area, the anterior set with 11 riblets, the posterior with 28. *Color:* yellow-white or pale green sometimes variegated with brown dots or splotches, rather iridescent.

M. aviarius occurs attached to the tests of large ascidians in Kaneohe Bay, Oahu, and in other bays in the islands. The valves are variable in size, color, and number of ribs. Because of the variability, I include three additional species described by Dall, Bartsch, and Rehder in the synonymy. A fourth species described from a dredge haul by the *Albatross* off the coast of Molokai at a depth of 32 meters may be distinguishable by the "pronounced keel" running from the umbones to the junction between the posterior and ventral margins, but specimens have not been obtained since the description of the type.

M. aviarius was described from the Hawaiian Islands.

Septifer bryanae (Pilsbry, 1921). Fig. 164 P, Q. Height, 12 mm; length, 7 mm; diameter, 7 mm. *Shell:* roughly triangular, inflated, moderately thin; beaks terminal; sculpture of fine radiating riblets crossed by concentric threads; green, lemon yellow, red, brown. *Margins:* anterior border rounded and ventral margin concave in the byssal region. *Sculpture:* with closely spaced, radiating riblets, the interspaces subequal, crossed by closely spaced concentric threads which are nodulose at the intersections. *Color:* variable — exterior and interior green, yellow, red, or brown; periostracum thin, with rather long, slender, scattered hairs.

These mytilids are common in shallow water and to depths of 26 m; they occur singly, attached by the byssus and nestled in the sand-algal turf of solution benches and in tide pools.

S. bryanae was described from the Hawaiian Islands and also occurs in the Marshall Islands.

Septifer rudis Dall, Bartsch, and Rehder, 1938. Fig. 164 G, H. Height, 13 mm; length, 8 mm; diameter, 8 mm. *Shell:* spatulate; inflated; moderately thin, beaks terminal and anterior end arched over by a septum; with roughly granulose radial ribs; cream-white mottled with red-brown. *Margins:* dorsal hinge line slightly convex; ventral margin deeply concave, almost incised at byssal area and gaping; anterior end with a heavy, medially incised shelf and with four tubercles above the shelf and a series of denticulations on the ventral edge opposite the shelf. *Sculpture:* radial riblets more prominent on the posterior half of the shell than anteriorly; concentric sculpture of threads much finer than the ribs. *Color:* exterior and interior white mottled with red-brown; periostracum thin, covering the wing only.

Valves of this mytilid are known only from dredged shells from depths of 30 to 100 m.

S. rudis was described from the Hawaiian Islands.

Terua crypta Dall, Bartsch, and Rehder, 1938. Fig. 164 R. Height, 4 mm; length, 1.5 mm; diameter, 1 mm. *Shell:* bean-shaped, thin; beaks terminal and anterior to the midline; with microscopic growth striae only; translucent brown. *Margins:* dorsal side slightly convex, anterior abruptly convex and posterior less so; ventral margin concave. *Sculpture:* microscopic incremental lines only. *Color:* translucent, with a thin, yellow, horn-colored periostracum.

This species occurs at depths of about 35 m off Oahu; it was described from the Hawaiian Islands. Habe (1977) records *T. crypta* from depths of 150 m off Esuzaki, Wakayama Prefecture, Honshu, Japan.

Additional Records

Mytilus bifurcatus Conrad, 1837, was erroneously described from the Hawaiian Islands; it is a common species in California.

A fossil species, *Septifer vaughni* Dall, Bartsch, and Rehder, 1938, occurs in Pleistocene deposits at Wailupe Quarry and Barbers Point, Oahu. The valves are large (height, 20 mm; length, 36 mm), thick and chiefly distinguished from *S. rudis* by their size. *S. kraussi* Kuster is reported as a Pleistocene fossil by Ostergaard (1928).

Terua pacifica Dall, Bartsch, and Rehder, 1938, was described from a single specimen dredged by the *Albatross* at a depth of 35 m off Oahu; it is 26 mm in height, 11 mm in length, bean-shaped, with the beaks nearer the midline than in *T. crypta*, pale brown in color, and there is an olive-green periostracum.

Representatives of two other mytilid genera have also been described from the Hawaiian Islands. *Modiolus bakeri* Dall, Bartsch, and Rehder, 1938, has a wedge-shaped, pale brown shell with the beaks strongly developed, incurved, and touching the dorsal border of the hinge line, and the anterior portion of the shell has radiating

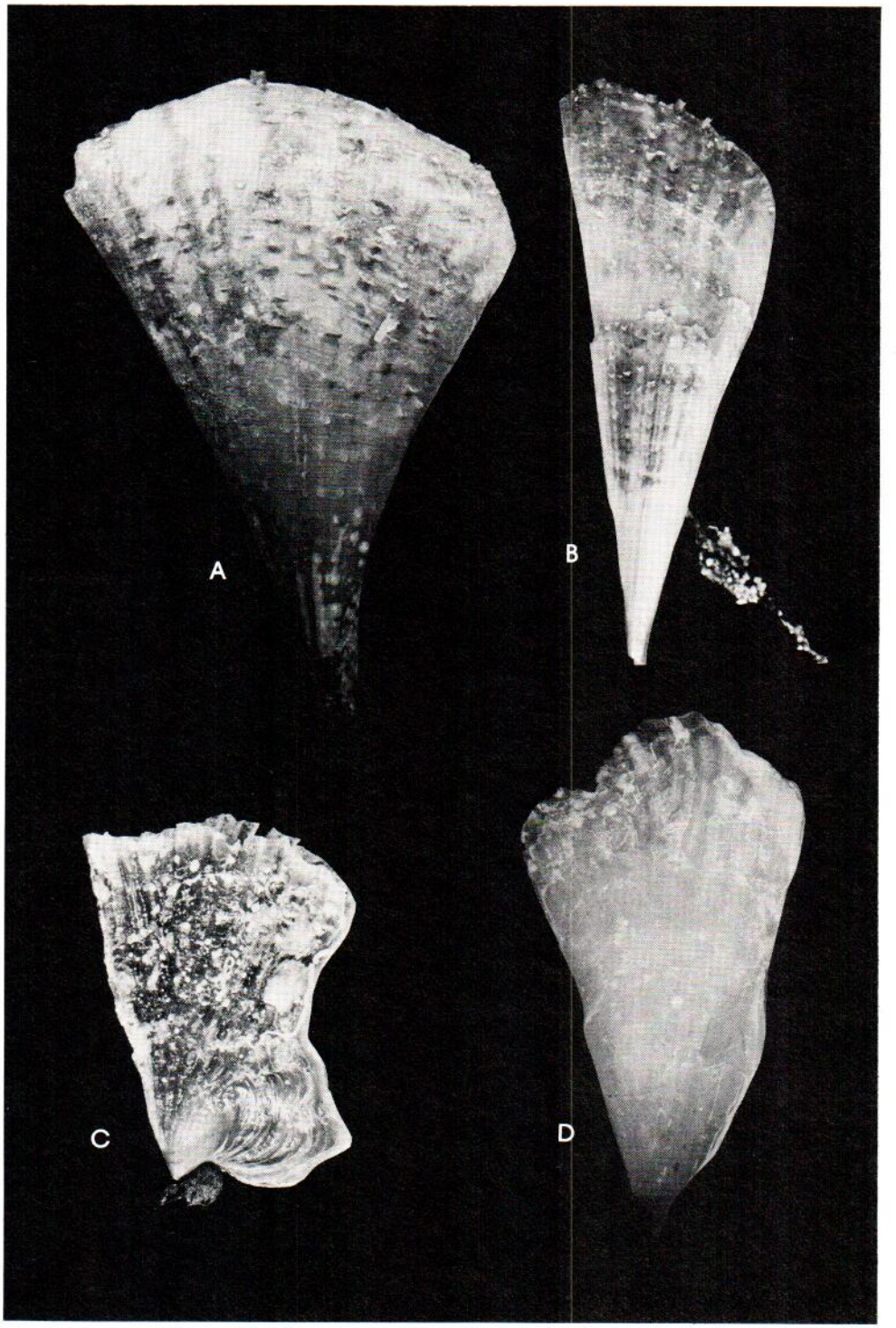


Figure 165.—**Pinnidae.** A. *Pinna bicolor,* height 200 mm. B. *P. muricata,* height 100 mm. C. *Streptopinna saccata,* height 115 mm. D. *Atrina vexillum,* height 235 mm.

threads; it was described from two broken valves collected in beach drift near Hilo, Hawaii. Specimens identified as *M. bakeri* have been found boring in limestone in the Tuamotus (Morrison, pers. comm.); an earlier name for the species may be *Modiola difficilis* (Deshayes, 1863) from Réunion. *Stenolena hawaiensis* Dall, Bartsch and Rehder, 1938, was described from a single valve dredged by the *Albatross* at depths of 12 to 16 m off Molokai; the valve is ovate, moderately thin-shelled, white, and with the apex pointed and terminal; the dimensions are: height, 2.8 mm; length, 1.8 mm.

Superfamily PINNACEA

Family **Pinnidae**

The pen shells are large, thin, triangular or fan-shaped, fragile bivalves which occur in shallow and deep waters of tropical and temperate regions. They are sedentary, living partially buried in a substrate of soft, sandy mud with the narrow, umbonal tip of the shell buried and anchored by the byssus. There are two adductor muscle scars. The shell consists of only two layers, an outer calcite layer and inner aragonite layer.

Atrina vexillum (Born, 1778). Fig. 165 D. (Synonyms: *Pinna oahua* Dall, Bartsch, and Rehder, 1938; *Atrina (Atrina) recta* Dall, Bartsch, and Rehder, 1938.) Height, 158 mm; length, 105 mm. *Shell:* triangular to hatchet-shaped, inflated, thick; with spinose radiating ribs; dull dark red-brown or black. *Sculpture:* occasionally with spinose radiating ribs. *Color:* semitranslucent, dark red-brown to black, surface usually dull.

These bivalves occur in sandy mud at depths of 3 m, but are uncommonly found in Hawaiian waters.

A. vexillum occurs throughout the Indo-West Pacific (Rosewater, 1961). The Hawaiian shells are usually much smaller than those found elsewhere.

Pinna bicolor Gmelin, 1791. Fig. 165 A. Height, 200 mm; length, 30 mm. *Shell:* broadly triangular, thin, fragile; a moderately strong triangular keel on the anterior half of the shell with flat radiating ribs; horn-colored to dark brown. *Sculpture:* radiating ribs which may bear flat tubular spines. *Color:* light horn to dark purple-brown, sometimes with radiating bands of alternating light and dark.

These bivalves are uncommon in the windward islands but abundant at depths of 50 m off Necker and Nihoa and others of the northwestern islands.

P. bicolor occurs throughout the Indo-West Pacific (Rosewater, 1961).

Pinna muricata Linnaeus, 1758. Figs. 158 D; 165 B. (Synonyms: *Pinna semicostata* Conrad, 1837; *P. exquisita* Dall, Bartsch, and Rehder, 1938; *P. hawaiiensis* Dall, Bartsch, and Rehder, 1938.) Height, 245 mm; length, 98 mm. *Shell:* attenuately triangular, thin, fragile; a moderately weak longitudinal keel on the anterior half of the shell with spinose radiating ribs; horn-colored. *Sculpture:* radiating ribs with upright spines. *Color:* translucent horn.

These bivalves are common in the soft, silty sand of tide pools and shallow waters inshore of fringing reefs, and abundant at depths of 60 to 100 m. An almost

continuous bed of *Pinna* occurs off the coast of leeward Oahu at depths of about 25 m, and beds up to 1500 m in diameter have been recorded at depths of 70 to 80 m between Maui and Lanai (Brock and Chamberlain, 1968). The bivalves lie almost in contact with one another, deeply buried in the substrate with only the lip of the shell protruding; they are attached by the byssus to coarse debris in the substratum.

P. muricata occurs throughout the Indo-West Pacific (Rosewater, 1961).

Streptopinna saccata (Linnaeus, 1758). Fig. 165 C. (Synonym: *Pinna nuttalli* Conrad, 1837.) Height, 235 mm; length, 78 mm. *Shell:* triangular, contorted; with coarse radiating ribs; gray-white to red-brown. *Sculpture:* five to twelve smooth or occasionally coarse radiating ribs. *Color:* translucent gray-white, tan, or dark red-brown.

Specimens of *S. saccata* are common at depths of 1 to 2 m where they grow in the sand around large boulders.

This species is distributed throughout the Indo-West Pacific (Rosewater, 1961).

Superfamily PTERIACEA

Family **Pteriidae**

The pearl oysters belong to this family, distinguished by shells which are aviculoid or suborbicular in shape and which have a pearly interior. There is a small anterior wing on each valve, and, in the right valve, a deep notch through which the byssus passes. The hinge is weak, almost toothless; the ligament is external. The inner layer of the shell is nacreous, the outer layer prismatic and lamellar, often developing a wide, darker colored border toward the ventral margin. There is a single adductor muscle scar.

Two genera are represented in Hawaiian waters, *Pinctada* (= *Margaritifera* of earlier workers) with orbicular or subquadrate shells, and a short hinge line, and *Pteria* (= *Avicula* of earlier workers) in which the hinge line is extended as a winglike structure. The pearl oysters are reef-living bivalves; the pterias are associated with gorgonids.

Pinctada margaritifera (Linnaeus, 1758). Fig. 166 D, E. (Synonyms: *Pinctada margaritifera mazatlanica* Jameson, 1901; *Margaritifera fimbriata* Dunker, Bryan, 1915; *Pinctada galtsoffi* Bartsch, 1931.) Height, 290 mm; length, 230 mm; diameter, 75 mm. *Shell:* oval to subquadrate, compressed, thick and solid; right valve less deep than the left; exterior laminated and covered with a yellow-olive periostracum, interior silvery gray, bordered by dark purple. *Margins:* dorsal straight; anterior, posterior, and ventral curved. *Hinge:* oblique, short, deep; byssal notch of right valve deeply infolded. *Sculpture:* exterior laminated and fimbriated in young specimens. *Color:* exterior gray, with a flaky, yellow-olive periostracum; interior lustrous, pearly gray with a blue to dark purple border.

The commercially important pearl oyster is uncommon around the shores of the main islands in the Hawaiian chain, only occasionally found at depths of 3 to 5 m and deeper. Pearl oysters were abundant at Pearl and Hermes Reef in the leeward islands

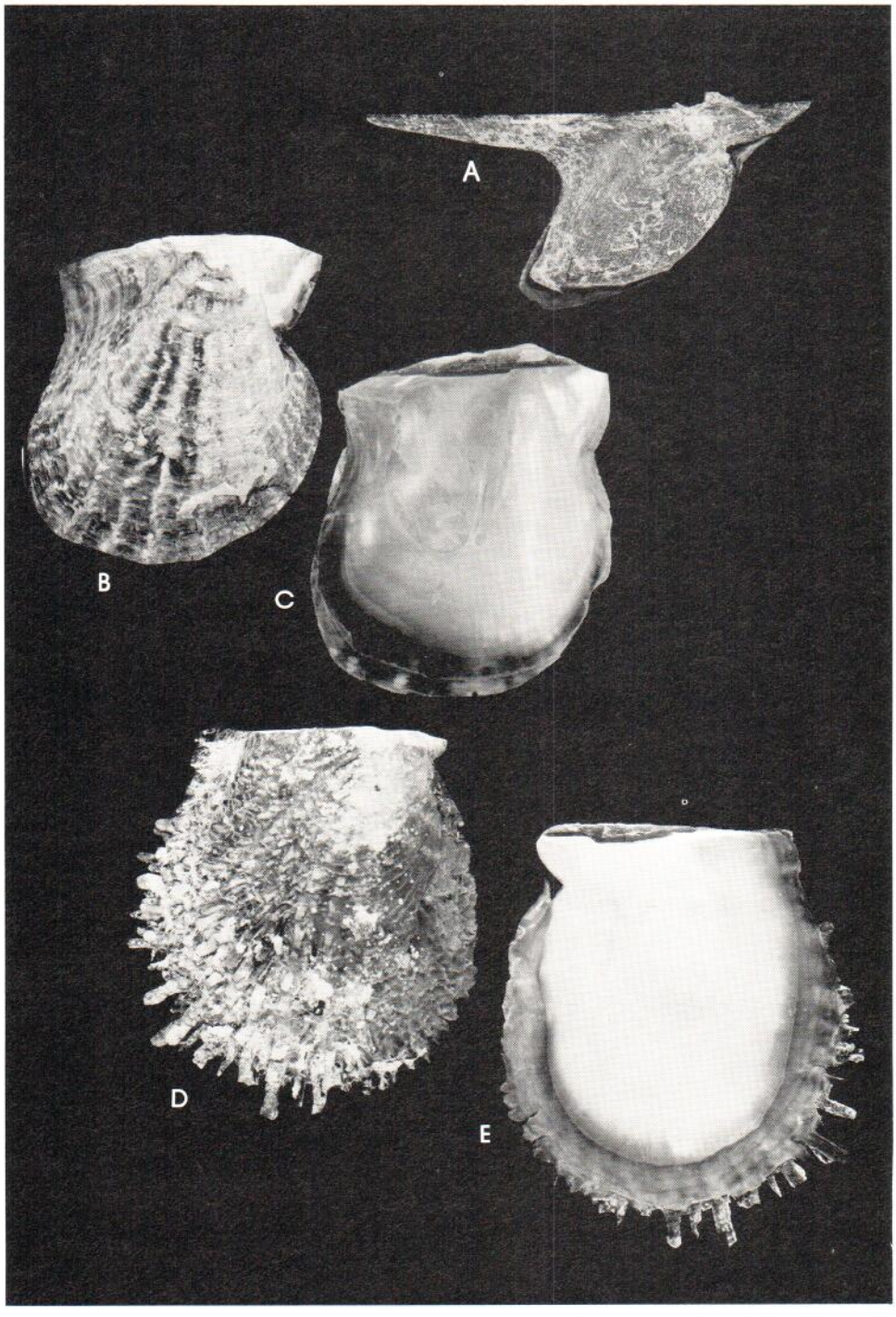


Figure 166.—**Pteriidae.** A. *Pteria brunnea*, height 24 mm. B, C. *Pinctada radiata*, height 60 mm. D, E. *P. maragaritifera*, height 290 mm.

in the 1920's, found in the lagoon at depths of 2 to 7 m standing vertically or in slightly inclined positions attached to corals (Galtsoff, 1933). The beds were decimated by oyster fishermen and have never recovered; only one or two living oysters have been seen in recent years at Pearl and Hermes Reef. Shells weighing up to fifteen pounds were reported in 1930 and adult oysters were ripe and spawning in July and August, 1930.

There seems no reason to distinguish the Hawaiian oysters from the black-lipped pearl oyster which occurs throughout the Indo-West Pacific, and I have followed Ranson (1961) in placing Bartsch's (1931) name in synonymy.

Pinctada radiata (Leach, 1814). Fig. 166 B, C. (Synonyms: *Avicula nebulosa* Conrad, 1837; *A. pallida* Conrad, 1837; *A. (Meleagrina) lichtensteini* Dunker, 1852b; *Pteria vulgaris* Schumacher, Lynge, 1909.) Height, 60 mm; length, 56 mm; diameter, 23 mm. *Shell:* oval to subquadrate; right valve a little smaller and less deep than the left; exterior with imbricated lamellae and scalelike elements; gray bordered with radiating bands of darker gray and white. *Margins:* dorsal straight; anterior, posterior, and ventral curved. *Hinge:* ligamental areas slightly oblique and long; hinge with a long slender medial fold strengthened into a denticle at each end. *Sculpture:* thin, imbricated lamellae whose free basal edge is more or less scalloped with scalelike elements, and with fine growth lines. *Color:* exterior gray bordered with radiating bands of darker and white and with a thin periostracum which is more or less marked with radiating bands of brown; interior lustrous pearl gray, the lateral and ventral border plain golden brown or variegated with dark and lighter areas.

This is a common shallow-water species along the shores of the main Hawaiian Islands, and juveniles are frequent on rocks in tide pools; it was formerly abundant in both Pearl Harbor and Kaneohe Bay, Oahu, where it was reported occasionally as a fouling organism (Edmondson and Ingram, 1939).

As in the case of *P. margaritifera* I have followed Ranson (1961) in including the small Hawaiian pearl oyster within the synonymy of a widespread Indo-West Pacific species. Conrad's (1837) *Avicula pallida* has never been satisfactorily identified, but it seems reasonable to include it within the synonym of *P. radiata,* although Hynd (1955) suggests it may be a synonym of *P. maculata* (Gould, 1850).

Pteria brunnea (Pease, 1863b). Fig. 166 A. (Synonym: *Pteria laciniata* Dall, Bartsch, and Rehder, 1938.) Height, 24 mm; length, 9 mm; diameter, 6 mm. *Shell:* oblique, with a long posterior wing and short anterior wing; right valve smaller and less convex than the left; beaks anterior to midline; brittle; sculpture of incremental lines; dark brown. *Margins:* beaks small and pointed; shell curving strongly toward the base below the byssal notch; posterior margin less curved. *Hinge:* ligamental area narrow. *Sculpture:* regularly spaced, wavy, incremental lines which are more concentrated on the wings than on the central area. *Color:* dark brown; periostracum brown and thin, projecting on the right valve from the growth lines.

P. brunnea is associated with the black coral *Antipathes grandis* Verrill, which occurs at depths of more than 30 m; the oyster is found at the base of the coral, firmly attached by a strongly developed byssus, the wing oriented parallel to the branches (Grigg, 1964).

This species was described from the Hawaiian Islands.

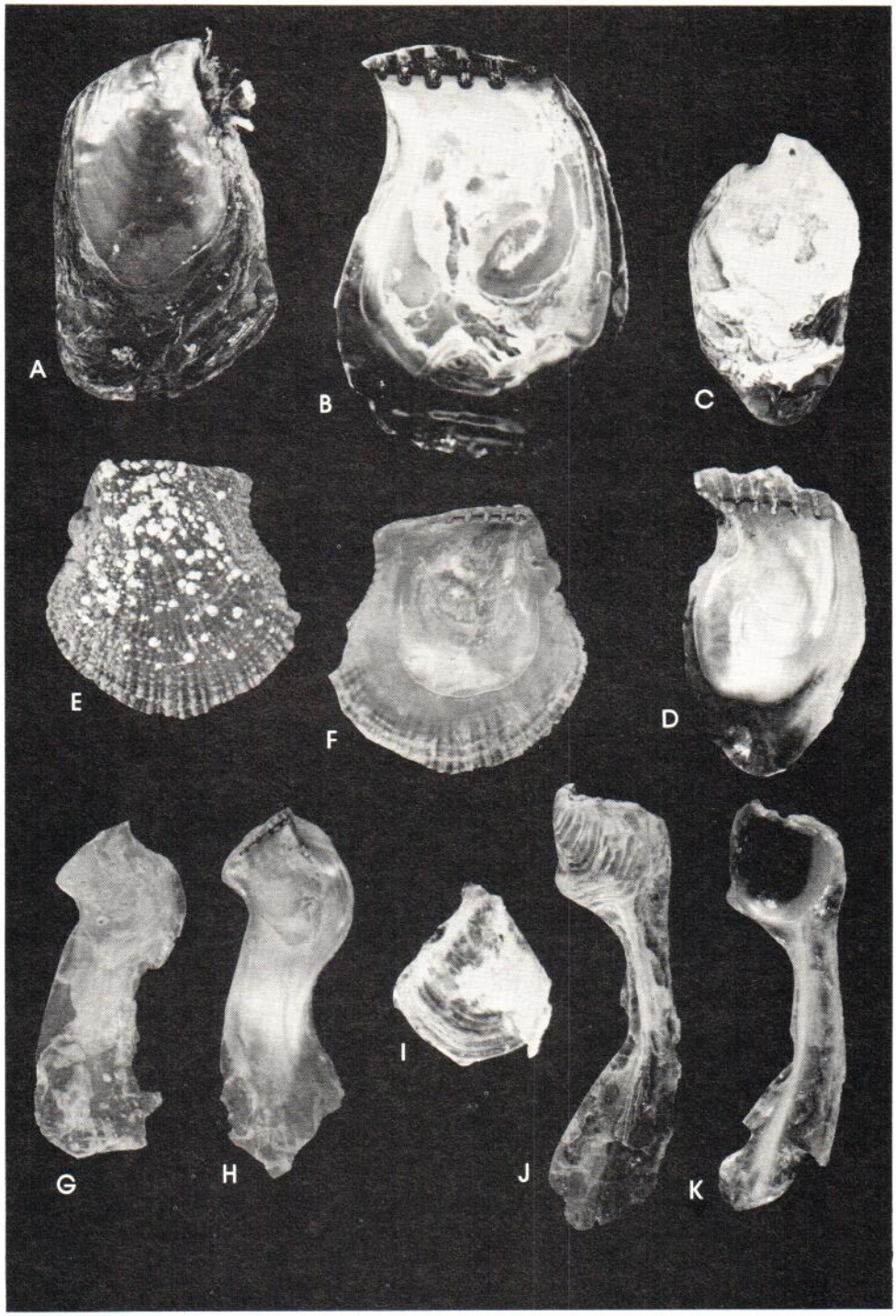


Figure 167.—A, B. *Isognomon californicum*, height 40 mm. C, D. *I. perna*, height 40 mm. E, F. *I. incisum*, height 59 mm. G, H. *I. legumen*. I, J, K. *Malleus regula*, juvenile (I) length 10 mm; adult (J, K) length 46 mm.

Family **Isognomonidae**

The distinguishing feature of the toothed pearl shells is a divided ligament which is lodged in a series of pits along the hinge. The valves are flat, somewhat irregularly shaped, and often have a scaly texture; they are nacreous internally and there is a single adductor muscle scar. These bivalves are sedentary, usually attached to the substrate by a strong byssus.

Isognomon californicum (Conrad, 1837). Figs. 158 E; 167 A, B. (Synonyms: *Perna hawaiiensis* Pease, 1871d; *Isognomon vitrea* (Reeve), Smith, 1885.) Height, 41 mm; length, 24 mm; diameter, 7 mm. *Shell:* rhomboidal, compressed; equivalve and equilateral; smooth with concentric lamellae; dark purple-brown. *Margins:* umbones forming a moderately prominent beak; byssal notch moderately deep; posterior margin curved. *Hinge:* with seven or eight ligamental pits. *Sculpture:* outer layer with thin, subimposed lamellae. *Color:* exterior dark brown to purple-brown; interior pearly gray with the border almost black; periostracum dark brown or purple.

These bivalves form dense beds attached to the substrate at the tide line in brackish water on Hawaii and Maui, and are found singly in more saline environments throughout the Island chain. They have a mytilid habit, and, despite their byssus, are able to move about on a large foot which is protruded between the valves when the animals are disturbed. Juvenile shells are smooth and ovate; adults are often weathered, heavy, and irregular in shape.

I. californicum was erroneously described from California from shells collected in the Hawaiian Islands by Nuttall but described by Conrad (1837).

Isognomon incisum (Conrad, 1837). Fig. 167 E, F. (Synonym: *Perna torva* Gould, 1850.) Height, 59 mm; length, 33 mm; diameter, 12 mm. *Shell:* ovate or irregular, heavy; left valve deeper and larger than the right; exterior light horn color, interior with a dark margin. *Margins:* byssal notch strongly incised. *Hinge:* with five or six ligamental pits. *Sculpture:* outer layer with variously developed concentric lamellae and wide, low radiating ribs. *Color:* exterior dark toward the ventral margin; interior smoky gray bordered by a marginal zone of black or purple. The shells are usually encrusted with heavy growths of calcareous algae.

These bivalves are common crevice dwellers and are found firmly attached by the byssus between boulders and in crevices in tide pools and on fringing reefs.

I. incisum was described from the Hawaiian Islands.

Isognomon legumen (Gmelin, 1791). Fig. 167 G, H. Height, 43 mm; length, 14 mm. *Shell:* elongate, tongue-shaped, compressed; with concentric lamellae and faint radial riblets; cream. *Margins:* beaks overhanging byssal sinus; hinge line oblique; ventral margin curved. *Hinge:* narrow, with five to seven ligamental pits. *Sculpture:* concentric lamellae, sometimes with faint radiating riblets. *Color:* cream; interior glossy, white.

These bivalves are uncommon, found at depths of 10 to 80 m.

I. legumen is widely distributed in the Indo-West Pacific, from the Red Sea through the Pacific.

Isognomon perna (Linnaeus, 1767). Fig. 167 C, D. (Synonyms: *Perna costellata* Conrad, 1837; *Isognomon samoensis* Baird, Smith, 1885.) Height, 48 mm; length, 41 mm; diameter, 11 mm. *Shell:* ovate, compressed; left valve usually a little larger and deeper than the right; laminated and with radiating riblets; buff with brown radiations. *Margins:* beaks hanging over the byssal sinus; hinge line oblique; varying in shape but posterior margin usually evenly curved. *Hinge:* broad, with six to nine ligamental pits. *Sculpture:* wavy, broad, low radiating riblets increasing basally by intercalations; finely spaced growth lines; usually laminated. *Color:* buff, the depressed spaces between the riblets brown on the upper valve only; interior pearl gray with a buff border.

These bivalves are abundant under rocks and rubble on fringing reefs and in tide pools where they may often be found growing one on top of another. The byssus and valves are shelter for small gastropods such as *Caecum, Rissoina, Lophocochlias,* and *Odostomia.* A small polyclad, *Pericellis,* is sometimes also associated with the bivalves (Poulter, 1963).

I. perna ranges through the Indo-West Pacific from Madagascar and the Seychelles to Micronesia and Polynesia.

Family **Malleidae**

This family is distinguished from other pteriaceans by the posteroventrally directed growth form; the shells are long and thin with an internal rib on the internal surface. The proximal portion of the shell is calcareous, the distal part of an organic matrix. There is a single, well-developed intrusive ligament. The best known member of the group is *Malleus malleus* (Linnaeus, 1758), the hammer oyster, in which the hinge line is bilaterally extended.

Malleus regula (Forskål, 1775). Fig. 167 I-K. (Synonym: *Vulsella nuttalli* Conrad, 1837.) Height, 46 mm; length, 15 mm. *Shell:* tongue-shaped, contorted, thin and fragile to heavy; proximal portions calcareous, lamellose, distal portion horny; interior nacreous, with a pallial rib; horn-colored to purple-brown. *Margins:* byssal sinus deeply cut in left valve, complementary area in right valve infolded. *Hinge:* ligamental area broad with an oblique resilium which bulges below the hinge anterior to the midline. *Sculpture:* early portions of the shell calcareous, lamellose, sometimes with wavy, radiating riblets; distal portions horny, of plates of organic matrix; pallial rib protruding on interior, extending from the distal end of the calcareous part of the valve to the margin. *Color:* exterior horn-colored to dark purple at the distal end; interior nacreous, often dark purple proximally.

Specimens of *M. regula* are found attached to coral and calcareous blocks, either firmly fastened by the byssus in crevices or in holes within the substrate. Immature specimens (Fig. 167 I) are common in coral blocks at depths of less than a meter; more fully developed valves have been dredged at depths of from 1 to 35 m. The habitat of *M. regulus* is similar to that of the conchologically similar Caribbean species *M. candeanus* (D'Orbigny, 1842) (Boss and Moore, 1967).

This species is widely distributed in the Indo-West Pacific from the Red Sea and Persian Gulf through the Pacific Ocean (Barnard, 1964).

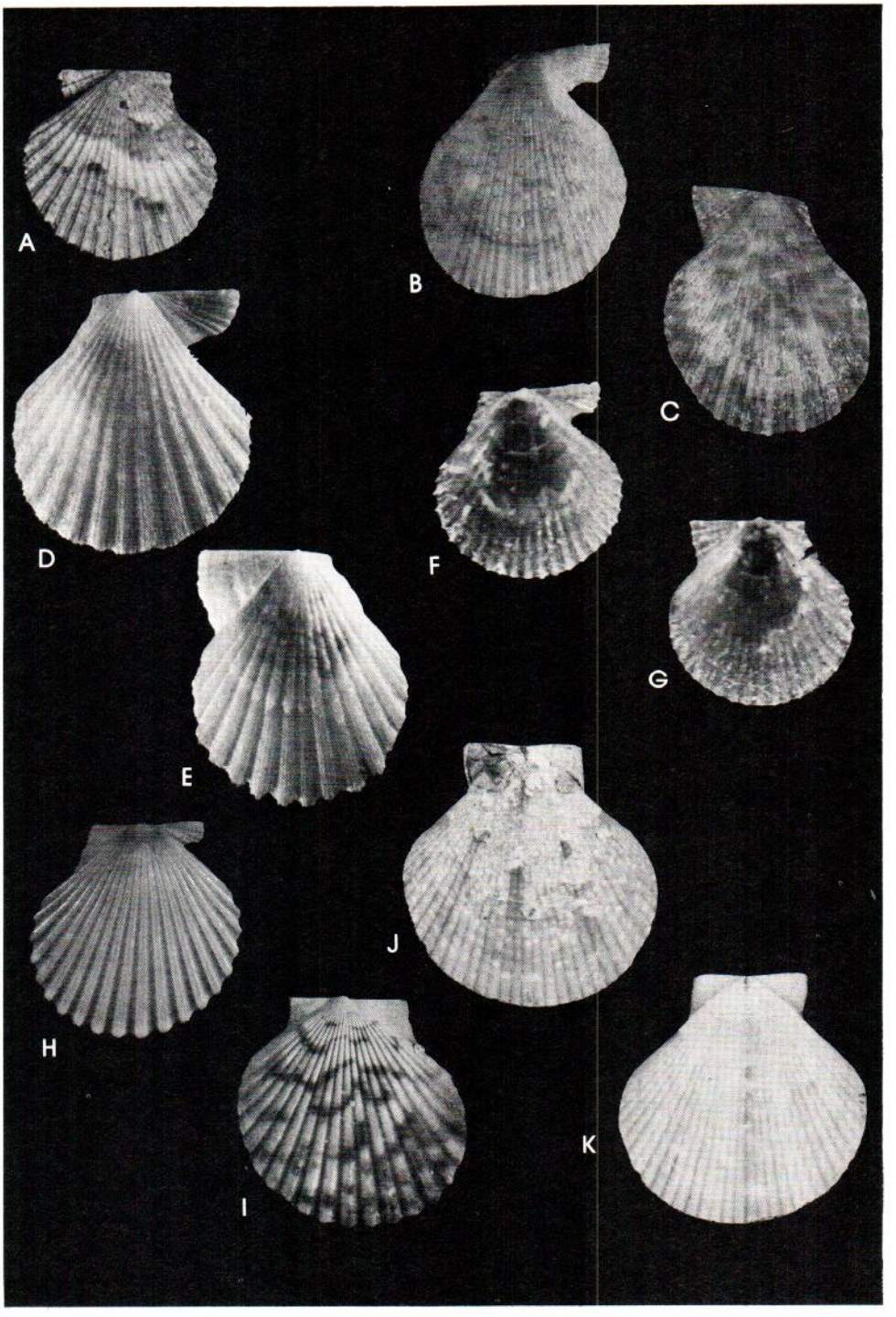


Figure 168.—**Pectinidae.** A. *Chlamys alli,* height 22 mm. B, C. *C. irregularis,* height 32 mm. D, E. *C. coruscans hawaiensis,* height 12 mm. F, G. *C. kauaiensis,* height 8 mm. H, I. *Haumea juddi,* height 19 mm. J, K. *Anguipecten lamberti,* height 36 mm.

Superfamily PECTINACEA

The five families included in the Pectinacea are among the most readily differentiated assemblages of bivalves, with subcircular, auricle-bearing shells and a single adductor muscle scar. These bivalves lie flat with the right valve always against the substrate. The Dimyidae, Spondylidae, and Plicatulidae (not represented in Hawaii) are sedentary. The pectens (Pectinidae and Propeamussidae) are free-moving, and some swim by clapping their valves together.

Family **Pectinidae**

The pectens or scallops comprise a large group of bivalves which are most abundant and attain their largest size in temperate waters. Pecten shells are more or less circular in outline with a straight hinge and two projections or auricles on each valve along the straight line of the hinge. The right valve is usually identified by a notch through which the byssus passes, found below the anterior auricle. The shell is equivalve in some genera, inequivalve in others. The external surface of the valves is usually radially ridged and often tinted in bright colors.

Young pectens lie with the right valve against the substrate, attached by the byssus; older animals may be free-swimming and move about by flapping the valves together and propelling themselves by jets of water expelled from the mantle cavity. Unlike most bivalves, the scallops have numerous eyes or ocelli along the edge of the mantle that are sensitive to light.

In the Hawaiian Islands living pectens are seldom seen on the reefs or in inshore waters because most local forms live at depths of several meters from whence their shells may be cast up on the beaches.

Subfamily **Pectininae**

The Hawaiian Pectininae may be keyed as follows:

1. Ribs nodulose or spiny 2
   Ribs neither strongly nodulose nor spiny 3
2. (1) Orbicular; red and yellow, ribs nodulose ..... *Decatopecten noduliferum*
   Angular; red and white; ribs spiny ..... *Mirapecten mirificus*
3. (1) Both auricles strongly developed 4
   Anterior auricle only developed 5
4. (3) Valves equally convex, obliquely suborbicular, left valve white, right valve brown and white ..... *Haumea juddi*
   Left valve only strongly convex, cream ..... *Pecten diomedeus*
   ..... *P. waikikius*
5. (3) Posterior auricle small but developed 6
   Posterior auricle barely indicated 7
6. (5) Radiating ribs subdivided into finer threads; white to pink ..... *Chlamys coruscans hawaiensis*
   Radiating ribs not subdivided but alternating strong and slender; red and yellow ..... *Chlamys irregularis*
7. (5) Hinge with teeth ..... *Anguipecten lamberti*
   Hinge without teeth ..... *Chlamys alli*

Anguipecten lamberti (Sowerby, 1874). Fig. 168 J, K. (Synonym: *Anguipecten gregoryi* Dall, Bartsch and Rehder, 1938.) Height, 36 mm; length, 34 mm; diameter of a single valve, 6.5 mm. *Shell:* subcircular, thin, compressed; wings of about equal size and lacking a byssal notch; with low, rounded, evenly spaced ribs crossed by fine, concentric striae; ventral edge of shell scalloped; maculated red, orange, yellow. *Hinge:* short; with a tooth on the anterior edge, another medially, and two oblique folds bounding the resilial pit. *Auricles:* lateral margins straight; anterior auricle smooth except for closely spaced concentric lamellae; posterior auricle with radiating threads and concentric lamellae. *Sculpture:* 30 to 40 low, rounded primary ribs subdivided by two or three radial threads, the ribs of slightly greater diameter than the interspaces; ribs and interspaces crossed by fine, closely spaced concentric lamellae often fusing with the adjacent lamellae and roofing over the ribs. *Color:* orange, rendered somewhat chalky by the concentric lamellae.

Valves have been dredged from depths of 30 to 600 m.

A. lamberti was described from New Caledonia. *A. gregoryi* was described from the Hawaiian Islands.

Chlamys alli Dall, Bartsch, and Rehder, 1938. Fig. 168 A. Height, 22 mm; length, 23 mm. *Shell:* subcircular, thin; equivalve; anterior and posterior auricles of almost equal size; ribs sharp, serrated; white freckled with red. *Hinge:* resilial pit broad, triangular and denticulated. *Auricles:* anterior auricle of right valve with a well-incised byssal notch; anterior and posterior auricles with radiating threads. *Sculpture:* right valve with 20 and left valve with 19 sharp, serrated ribs, the interspaces wide and shallow with four smaller, serrated threads. *Color:* white freckled with red.

This is a deep-water pecten; valves were dredged by the *Albatross* at depths of 496 m and more recently by the *Pele* at lesser depths.

C. alli was described from the Hawaiian Islands.

Chlamys coruscans hawaiensis Dall, Bartsch, and Rehder, 1938. Fig. 168 D, E. Height, 12 mm; length, 11 mm; diameter, 5 mm. *Shell:* subcircular, thin; right valve more convex than the left; anterior auricle only strongly developed; strong radiating ribs subdivided by finer threads; ventral margin fluted and scalloped; white to pink. *Auricles:* anterior auricle with a decided byssal notch in the right valve, an indentation in the left valve, and with six or seven strong cords and irregular concentric lamellae; posterior auricles much smaller than anterior. *Hinge:* finely, transversely denticulated and obscurely longitudinally grooved; resilial pit deep. *Sculpture:* 15 to 17 convex, primary ribs subdivided by four smaller, convex imbricated threads; interspaces shallow and subequal, with similar slender threads. *Color:* cream, sometimes spotted with brown.

This is the only shallow-water pecten in the Hawaiian Islands, found attached to rocks and in the sand-algal turf of tide pools, and to depths of 10 m where it may be byssally attached beneath the coral *Porites lobata* (Waller, 1972). *C. c. hawaiensis* is a common fossil in the upper portions of the Sand Island and Reef drill holes at Midway (Ladd, Tracey, and Gross, 1967).

C. c. hawaiensis is distinguished from *C. c. coruscans* (Hinds, 1845) of the Indian Ocean and west and central Pacific by the narrower umbonal angle, smaller

posterior auricles with more strongly developed posterior cardinal crura, four or five posterior auricular denticles rather than three, and a slightly greater tendency to develop 16 primary plicae (Waller, 1972).

Chlamys irregularis (Sowerby, 1842). Fig. 168 B, C. (Synonyms: *Pecten (Chlamys) albolineatus* G. B. Sowerby, Ostergaard, 1928; *P. cuneatus* Reeve, 1853, Hertlein, 1935; *Chlamys cookei* Dall, Bartsch and Rehder, 1938; *C. midwayensis* Habe and Okutani, 1968.) Height, 32 mm; length, 27 mm; diameter, 10 mm. *Shell:* subcircular, thin, barely inflated; inequivalve; ribs imbricated, the primary ribs alternating with secondaries; ventral border slightly fluted; white to yellow, blotched with red and brown. *Auricles:* right anterior auricle strongly developed, with a deep byssal notch and seven or eight strong cords; posterior auricle short with poorly developed cords tending to bear scales. *Hinge:* transversely denticulated; with a strong, oblique fold below the ligamental area; resilial pit narrow and deep. *Sculpture:* right valve with 40, left valve with about 80, fine ribs imbricated toward the edge of the shell, the interspaces of lesser diameter, stronger cords alternating with finer threads. *Color:* white to yellow variegated with red and brown blotches; interior rose or yellow, spotted with darker.

These pectens are uncommon, occurring at moderate depths of from 12 to 150 m, often inside reefs attached by the byssus to seaweed. They were abundant in Kaneohe Bay, Pearl Harbor, and Honolulu Harbor, Oahu, during the 1920's but do not now occur in these areas. Pleistocene fossils from Oahu are reported (as *C. albolineatus)* by Ostergaard (1928).

C. irregularis was described from "Eastern Seas"

Chlamys kauaiensis Dall, Bartsch and Rehder, 1938. Fig. 168 F, G. Height, 6 mm; length, 6 mm. *Shell:* subcircular, thin; with about 25 radiating ribs; cream, yellow, or orange-red. *Hinge:* narrow, with sharp denticulations. *Auricles:* auricle of right valve strongly produced, with four or five radiating threads, byssal notch small; posterior auricle narrow and with two or three slender threads. *Sculpture:* 23 to 28 regular, slightly scaly radiating ribs, about one-third as wide as the interspaces, becoming somewhat reduced toward the umbones; with fine incremental lines and scratches. *Color:* variable — orange-red, cream, yellow.

Valves of this pecten have been dredged at depths of from 200 to 600 m.

C. kauaiensis was described from the Hawaiian Islands.

Decatopecten noduliferum (Sowerby, 1842). Fig. 169 C, D. (Synonym: *Nodipecten langfordi* Dall, Bartsch, and Rehder, 1938.) Height, 20 mm; length, 20 mm; diameter, 11 mm. *Shell:* subcircular, thick and solid, strongly inflated; left valve nodulose; auricles equally developed; ribs stout, radiating, subdivided into finer cords; margins scalloped and denticulated; red and yellow. *Hinge:* resilium large and triangular, pitted on each side in right valve and toothed in left; teeth finely transversely grooved. *Auricles:* byssal notch V-shaped and shallow; auricles with five or six irregular, radiating cords. *Sculpture:* right valve with eight to ten stout ribs subdivided into finer cords, the interspaces subequal, shallow and threaded; left valve with nine nodular cords, the interspaces of equal diameter and threaded. *Color:* exterior — right valve yellow, left valve red; interior — hinge and midsection bright red, edge yellow.

D. noduliferum occurs at depths of from 10 to 100 m. Beachworn shells (which may lack the nodules of live-collected specimens) are common in drift along the northern shores of Kauai and Oahu.

There seems no reason to distinguish the Hawaiian shells described by Dall, Bartsch, and Rehder as *Nodipecten langfordi* from the widespread Indo-West Pacific species.

Haumea juddi Dall, Bartsch, and Rehder, 1938. Fig. 168 H, I. (Synonym: *Pecten loxoides* Sowerby, 1842, Hertlein, 1935.) Height, 19 mm; length, 18 mm; diameter, 7 mm. *Shell:* subcircular, moderately solid; inequivalve; both auricles strongly developed; ribs strong, smooth, and separated by deep interspaces; lateral and ventral edges scalloped; right valve white, left valve brown and white. *Hinge:* transversely sinuously striated; in right valve a median fold and an indication of a tooth on either side of the resilial pit. *Auricles:* anterior wing of right auricle with a shallow byssal notch; anterior auricles with rounded threads, posterior auricles almost smooth. *Sculpture:* about 21 smooth, convex ribs, the interspaces deep and smooth, of approximately equal diameter and with microscopic, sharp, concentric threads. *Color:* right valve white with a reddish spot at the umbo, left valve mottled and banded with red brown.

These pectens are common to abundant at depths of from 8 to 100 m. A bed of the pectens covering an area of about 10,000 square feet was observed at a depth of 50 feet off Pupukea, Oahu, in October, 1968, by Calabrese and Cook (pers. comm.). The pectens lay on the sand substrate with valves open, the upper valves covered with a thin layer of sand. When disturbed the pectens swam distances of 6 to 10 feet and then settled again. All were facing the rather strong current with the valves open.

H. juddi was described from the Hawaiian Islands.

Mirapecten mirificus (Reeve, 1853). Fig. 158 B; 169 A, B. (Synonym: *Mirapecten thaanumi* Dall, Bartsch and Rehder, 1938.) Height, 22 mm; length, 26 mm; diameter, 5 mm. *Shell:* angular, brittle; right valve more convex than the left; auricles strong; ribs strong, radiating, bearing spines, and extending beyond the edge of the shell; red variegated with white. *Hinge:* narrow, with fine transverse denticulations. *Auricles:* anterior auricle with one to five scaly cords, posterior auricle smooth. *Sculpture:* right valve with six pairs, left valve with five pairs, of broad ribs bearing hollow spines; interspaces of greater diameter than ribs. *Color:* red variegated with white or yellow.

M. mirificus occurs at depths of 140 to 198 m.

This species was described from the Philippines.

Pecten (?benedictus) diomedeus Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 54 mm; length, 60 mm. *Shell:* subcircular; inequivalve, right valve inflated; ribs broad, low, and rounded; pale brown. *Auricles:* anterior auricle of right valve with incremental, closely spaced lamellae; posterior auricle with obsolete threads. *Sculpture:* (right valve only) — broad, low, rounded radiating ribs which show a tendency toward median grooving, ribs and interspaces crossed by closely spaced concentric lamellae. *Color:* pale brown.

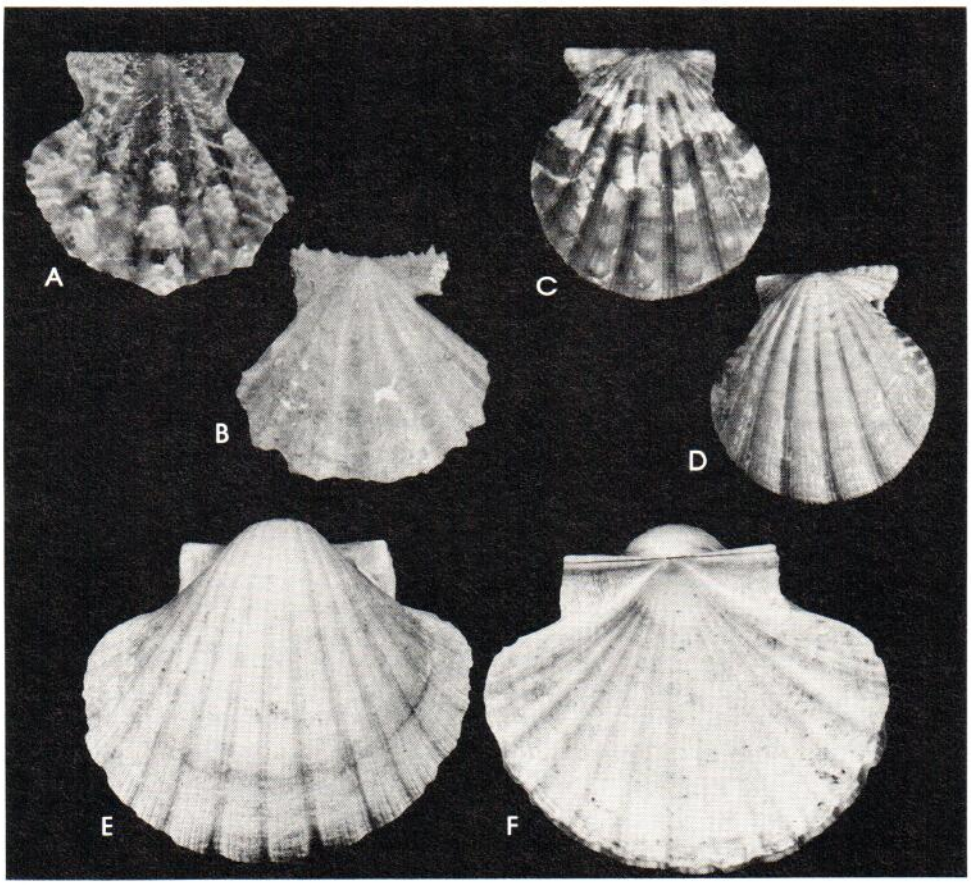


Figure 169.—**Pectinidae.** A, B. *Mirapecten mirificus*, height 22 mm. C, D. *Decatopecten noduliferum*, height 20 mm. E, F. *Pecten waikikius*, height 41 mm.

This species is known only from the type, which was dredged at a depth of about 21 m by the *Albatross*, and from three left valves dredged by the *Pele*.

The Hawaiian shells may represent a race of the polytypic species *P. benedictus* which has a Recent range from the Mediterranean through the Indian and Pacific Oceans (Fleming, 1962).

Pecten waikikius Dall, Bartsch, and Rehder, 1938. Fig. 169 E, F. Height, 41 mm; length, 48 mm; diameter of upper valve, 7 mm. *Shell:* subcircular; right valve extremely inflated with high, swollen beaks, left valve concave; right valve with rounded primary ribs, secondary radial threads and concentric lamellae; white, variegated with old rose. *Auricles:* right auricle of right valve terminating in an almost straight line laterally, with five slender radiating threads, left auricle moderately arched at lateral edge and with three radiating threads. *Sculpture:* right valve with 11 to 16 strong, somewhat rounded radiating ribs, the interspaces of about equal diameter; ribs and interspaces with four or five secondary radial threads and crossed by fine, concentric lamellae; left valve with 13 to 14 smooth cords with one or two secondary

ribs and crossed by more conspicuous concentric lamellae than in right valve. *Color:* white variegated with old rose.

Valves of this species have been dredged from depths of 1 to 200 m.

Fleming (1962) suggests that *P. waikikius* is a member of the polytypic pecten *P. jacobaeus,* with races in the Mediterranean, Atlantic islands, New South Wales, New Zealand, Formosa and Okinawa, and Tasmania and southeast Australia.

Additional Records

Chlamys stearnsi Dall, Bartsch, and Rehder, 1938, is a fossil species from a Pleistocene deposit at Waianae Quarry, Oahu. *C. russatus* Reeve, 1853, was erroneously described from the Hawaiian Islands. A fragment identified by Waller (1972) as *Gloripallium* sp. cf. *G. pallium* (Linnaeus, 1758) was found in the 155-159 foot level Sand Island drill hole on Midway in sediments considered post-Miocene in age (Ladd, Tracey, and Gross, 1967). *Pecten tunica* R. A. Philippi, 1844, was erroneously described as "ad insulae Sandwich." The species is now considered a synonym of *Leptopecten latiauratus* (Conrad, 1837) from California (Hertlein, pers. comm.).

Family **Propeamusiidae**

In this family the shells are equivalved, usually rather small, thin, orbicular, laterally compressed, usually white and often transparent. The surface is smooth or with fine radial and concentric sculpture and the interior has fine radiating ribs. There is usually a distinct sinus under the right auricle. The five species described by Dall, Bartsch, and Rehder from Hawaiian waters, all except one from depths of more than 100 m, were based on sparse material and none has been discussed since the original description. A list of species with brief descriptions and a figure (Fig. 170 A, B) are included here to complete the record.

Species	Size	Distinguishing Features
Propeamussium diomedeum	6.5 x 6.5 mm	Right valve with closely spaced concentric threads; left valve with concentric threads and radiating ribs; interior with 10 radiating ribs, three intercalated short pieces.
P. kauaium	10 x 10 mm	Right valve with concentric threads crossed by radiating lirae; left valve with strong, hollow, rounded concentric cords with radiating threads between; interior with 10 radiating ribs.
P. molokaium	4.9 x 5.0 mm	Right valve with numerous concentric lamellae; left valve unknown; interior with 17 radiating ribs.
P. nesiotum	4.9 x 5.1 mm	Right valve with concentric lamina; left valve with concentric threads crossed by radiating ribs; interior with 12 radiating ribs.
P. pailoloum	9.2 x 9.5 mm	Right valve with concentric threads and axial lirations; left valve with concentric threads; interior with 10 radiating cords.

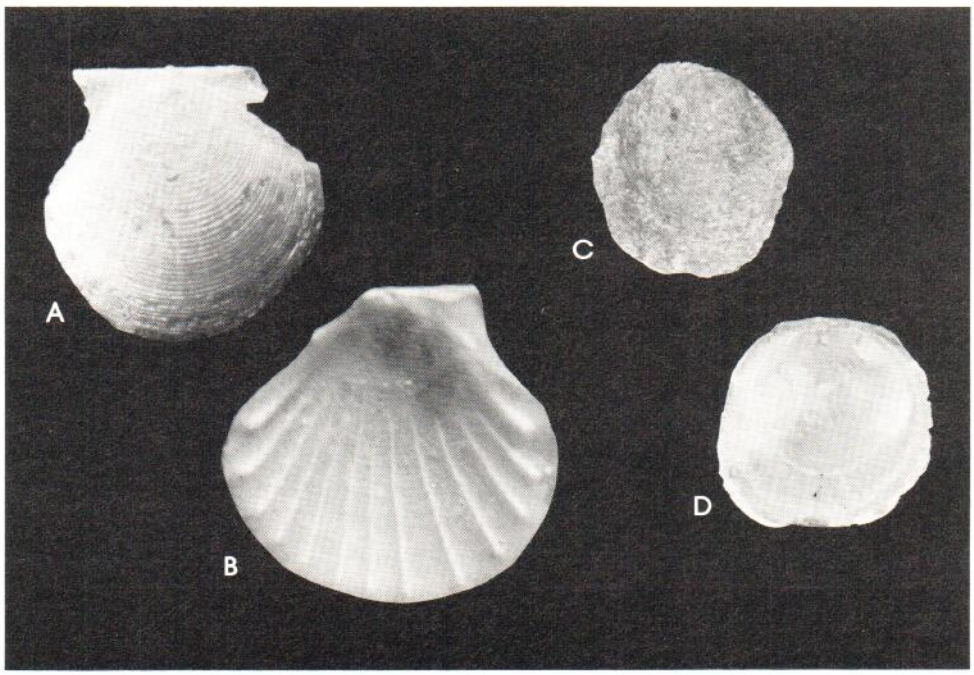


Figure 170.—A, B. *Propeamussium ?pailolum*, height 9 mm. C, D. *Dimya molokaia*, height 8 mm.

Family **Dimyidae**

This family comprises deep-water bivalves with shells which are usually flat and circular in outline but which vary in shape because the right valve is attached to the substrate. The ligament is internal, contained in a small round socket; there are two muscle scars. The exterior of the left valve is laminated and often flaky; the interior is nacreous.

Dimya mimula Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 14 mm; length, 13 mm; diameter of upper valve, 2.5 mm. *Shell:* circular, upper valve cap-shaped; scaly; yellow-white. *Hinge:* short, narrow and transversely grooved with a triangular tooth pointing inward. *Sculpture:* obliquely marked with concentric lamellae which present a scaly appearance. *Color:* yellow-white.

The type specimen was dredged by the *Albatross* at depths of 254 to 260 m off the south coast of Molokai.

D. mimula was described from the Hawaiian Islands. Although it resembles *D. lima* Bartsch, 1913, in size and shape, the hinge is longer and the tooth pronounced.

Dimya molokaia Dall, Bartsch, and Rehder, 1938. Fig. 170 C, D. Height, 8 mm; length, 7 mm; diameter of upper valve, 2 mm. *Shell:* obliquely ovate; upper valve cap-shaped, exterior laminated and like flakes of mica; white. *Hinge:* arcuate, narrow and transversely waved. *Sculpture:* concentric laminae which are free on the distal border, the laminae somewhat fluted toward the edge of the shell. *Color:* pearly white.

This is the more common of the two species of *Dimya* occurring in Hawaiian waters, and specimens are present on almost every piece of rock, coral, or solidified beach rock dredged from depths of 100 m or more.

D. molokaia was described from the Hawaiian Islands; it differs from *D. lima* Bartsch, 1913, from the Philippines which has a larger (14 mm in height), flatter shell without an arcuate hinge and internal rather than marginal crenulations.

Family **Spondylidae**

The Spondylidae or thorny oysters are, like the "true" oysters (Ostreidae), sedentary, attached by cementation of the right valve which is larger than the left. The shells are usually vividly colored in hues of orange, yellow, crimson, and violet, and the valves are radiately ribbed, often with scaly projections or long spines. There is a single adductor muscle scar. The hinge line is straight with a pair of large, curved or hook-shaped crural teeth and their sockets in each valve. The cardinal area is high and triangular in the right valve, absent in the left. The ligament is almost wholly internal, lodged in a deep pit between the crural teeth.

The spondyli are difficult to identify because of the variability of their most conspicuous characters. The spines may be long or obsolete, the colors in some species cover a wide range, and shell form is affected not only by the substrate to which they are attached but by crowding. To compound these difficulties, the young valves are often very different in sculpture and ornamentation from the older valves, and large shells are often heavily encrusted with calcareous growths. The form of the hinge in the attached valve and the minor sculpture of the upper valve are perhaps the most constant characters in the group.

Although Dall, Bartsch, and Rehder (1938) described seven species of *Spondylus* from the Hawaiian Islands, only three species are recognized here. With one exception *(Spondylus hawaiensis),* the valves described were juvenile.

Spondylus hystrix Bolten in Röding, 1798. Fig. 171 G, H. (Synonym: *Spondylus serratisimus* Dall, Bartsch, and Rehder, 1938.) Height, 80 mm; length, 72 mm. *Shell:* radial ribs developed, with long, hooked spines and the interspaces with fine, serrated spines; upper valve white with occasional splashes of purple-brown or red-brown. *Hinge:* finely denticulate. *Sculpture:* upper valve with 25 radial ribs bearing fully developed, long, hooked spines; interspaces of greater diameter with short, fine, serrated spines arranged in radial rows. *Color:* exterior white, with occasional splashes of red-brown. Interior white, with the exterior spots of red-brown showing through.

These spondylids are found at depths of from 3 to 124 meters.

S. hystrix is a well known species in the Indo-West Pacific. Fulton (1915) noted that the development of the spines is very variable, some specimens having numerous and closely set spines, others are almost smooth. In color they vary from white to almost purple-brown. The valves of *S. serratisimus* Dall, Bartsch, and Rehder, 1938, are juvenile, and indistinguishable from those of the types of *S. ciliatus* Sowerby in the British Museum (Natural History). Fulton (1915) includes *S. ciliatus* in the synonymy of *S. hystrix*.

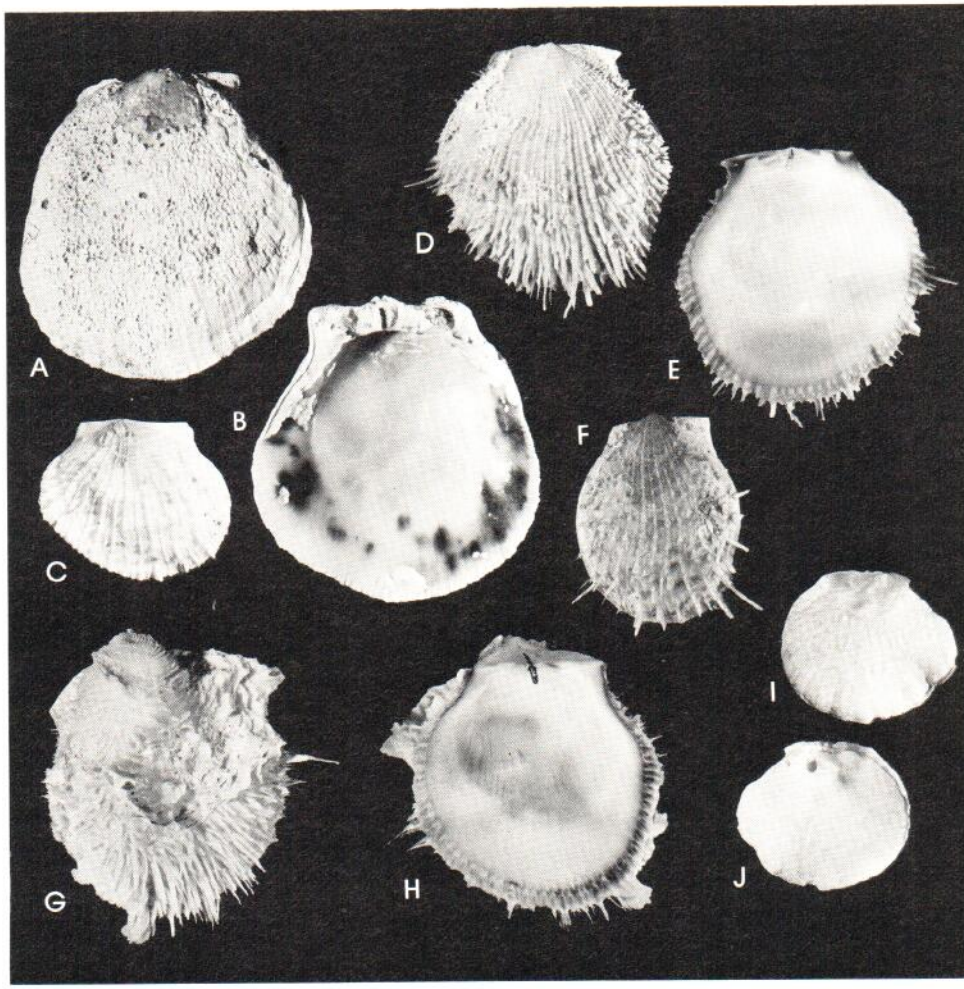


Figure 171.—**Spondylidae** and **Anomiidae.** A, B, C. *Spondylus tenebrosus,* height 70 mm (A, B) and 15 mm (C). D, E, F. *S. linguaefelis,* height 56 mm (D, E) and 20 mm (F). G, H. *S. hystrix,* height 65 mm. I, J. *Anomia nobilis,* height 48 mm (type).

Spondylus linguaefelis Sowerby, 1847. Fig. 171 D-F. (Synonyms: *Spondylus gloriosus* Dall, Bartsch, and Rehder, 1938; *S. mimus* Dall, Bartsch, and Rehder, 1938; *S. kauaiensis* Dall, Bartsch, and Rehder, 1938.) Length, 95 mm; diameter, 75 mm. *Shell:* lower valve shallow; elongate-ovate with a rosy background and long yellow spines. *Sculpture:* 20 or more radiating ribs decorated with long spines. *Color:* background rosy red, spines yellow. Interior tinted with rose, with the radial striations showing through.

These spondylids are found at depths of 40 m. The types of the Dall, Bartsch, and Rehder species were dredged by the *Albatross* at depths of 4 to 80 m.

The three species described by Dall, Bartsch, and Rehder which are included in the synonymy were described from juvenile shells. *Spondylus gloriosus* was reported from Clipperton Island (Hertlein and Allison, 1966).

Spondylus tenebrosus Reeve, 1856. Fig. 171 A-C. (Synonyms: *Hinnites giganteus* Gray, Bryan, 1915; *Spondylus zonalis* Lamarck, Hertlein, 1935; *S. hawaiensis* Dall, Bartsch, and Rehder, 1938.) Length, 69 mm; diameter, 77 mm. *Shell:* lower valve cuplike, attached only at the umbone; radial ribs flatly spinose; interior white, edged with purple-brown. *Hinge:* with three to five sockets. *Sculpture:* lower valve with radial ribs and flutings, radiae with rather flat spines; upper valve with flatly spined ribs, the interspaces of greater diameter and with three to eight radial, nonspinose threads. *Color:* white near the beak and on the radial ribs and flutings; purple toward the margins, lateral teeth and sockets deep brown, medial tooth white. Interior white to brown, margined with purple-brown.

This is the most commonly occurring of the Hawaiian spondyli, found in tide pools and on fringing reefs. It is especially distinguished by its large, heavy shell which is usually thickly encrusted with calcareous growths. The valves may weigh up to .9 kgm and the species therefore represents Hawaii's largest bivalve (Anon., 1962b). Juvenile shells are flat with red radiating ribs.

S. tenebrosus was described from Moreton Bay, Australia, and also occurs in the Gilbert and Marshall Islands.

Superfamily ANOMIACEA

Family **Anomiidae**

The distorted shells of the saddle oysters or jingle shells superficially resemble those of the true oysters, but their mode of attachment, a byssal plug passing through an opening in the umbone of the right valve, and their delicate, somewhat transparent shells distinguish them. The shells are inflated, nearly equilateral, distinctly inequivalve, and the hinge is edentulous.

Anomia nobilis Reeve, 1859. Fig. 171 I, J. Height, 48 mm; length, 68 mm. *Shell:* orbicular, irregular and distorted, thin; right (lower) valve with a perforation; upper valve moderately convex; milk-white to pale green. *Sculpture:* scalelike, concentric lamellae which at times are free at the distal edge; with lines of growth and closely spaced, irregularly slanting radiating threads. *Color:* variable — milk-white, cream, yellow, pale green.

This is a characteristic fouling organism in Hawaiian waters and numerous specimens may be piled one on top of the other on waterlogged boards and pilings in Pearl Harbor (Edmondson, 1944b) and Kaneohe Bay, Oahu.

A. nobilis was described from the Hawaiian Islands, but is widely distributed in the Indo-West Pacific.

Additional Record

A. tyria Reeve, 1859, described from the Islands, is smaller than *A. nobilis* (type dimensions: height, 36 mm), and dark purple with some white maculations. Specimens comparable with the type have not been found in recent years.

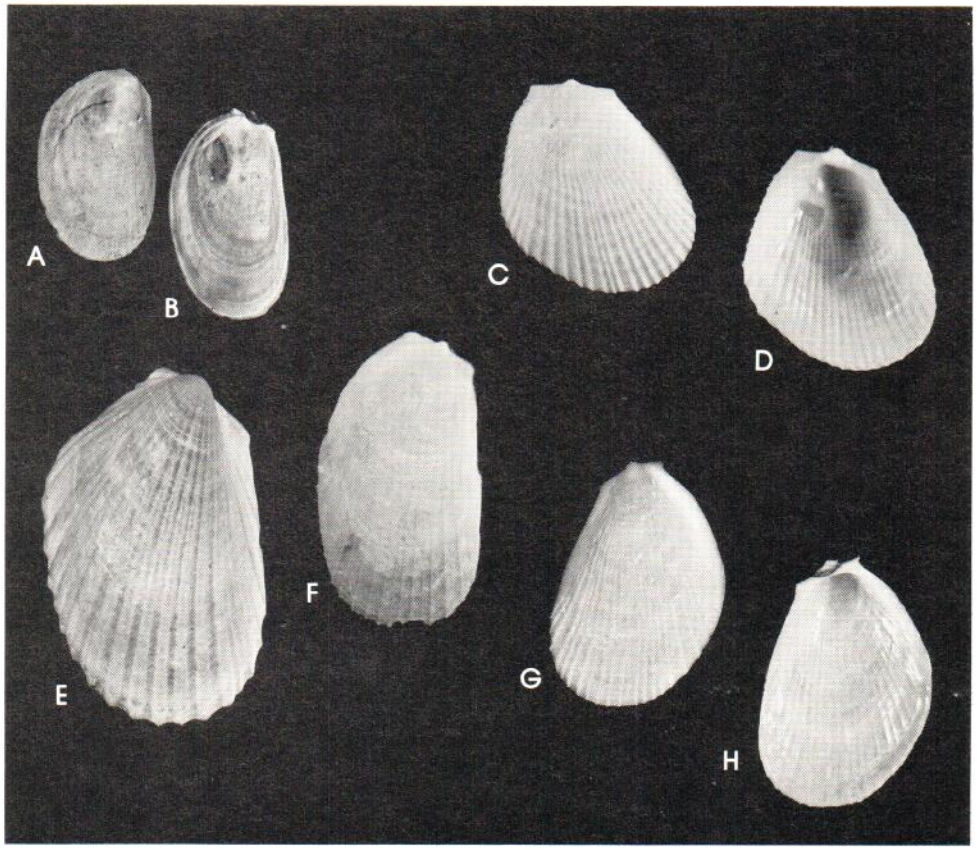


Figure 172.—**Limidae.** A, B. *Lima fragilis,* height 29 mm. C, D. *L. lahaina,* height 19 mm. E. *L. hawaiana,* height 15 mm. F. *L. parallela,* height 8 mm. G, H. *L. keokea,* height 16 mm.

Superfamily LIMACEA

Family **Limidae**

The auricles on the limas or file shells are reminiscent of those of the pectens, and some limas, like the pectens, can swim. The shells are elongate-ovate, equivalve and inequilateral, the beaks anterior to the midline. The sculpture consists of fine or coarse, sometimes scabrous, radial ribs; the lateral margins of the shell may be thickened. There is a single adductor muscle scar. The hinge is straight and edentulous and the ligament is internal in a pit. The shells are white or cream colored and the animals may be brilliant red.

Limas are often found burrowed into the substrate in nests constructed of rubble cemented together. The animals are unable to withdraw completely into their shells and when they feed the long, delicate tentacles which line the mantle edge extend well beyond the edges of the shell (Fig. 158 F).

All limas found in the Hawaiian Islands are thin, fragile, spineless forms.

Lima fragilis Chemnitz, 1784. Fig. 172 A, B. (Synonym: *Lima auaua* Dall, Bartsch, and Rehder, 1938.) Height, 29 mm; length, 18 mm; diameter, 9 mm. *Shell:* obliquely oval, compressed, gaping; light and thin; anterior wings smaller than posterior; anterior and posterior margins smooth; radiating ribs on central portion; white. *Auricles:* anterior and posterior with lines of growth. *Hinge:* ligamental area broad; hinge plate terminating in a sharp point. *Sculpture:* slender, radiating ribs becoming lamellar toward the ventral margin, interspaces of greater diameter and often with intercalated threads; concentric sculpture of fine spiral striae becoming stronger ventrally. *Color:* white. *Animal:* red.

These bivalves are found at depths of from 8 to 100 m.

L. fragilis occurs through the Indo-West Pacific from the Cocos Keeling Islands to Hawaii.

Lima hawaiana Dall, Bartsch, and Rehder, 1938. Fig. 172 E. Height, 15 mm; length, 10 mm; diameter, 8 mm. *Shell:* trapezoidal, inflated, light and thin; ribs broad, rounded and with microscopic concentric threads; lateral and ventral margins scalloped; white. *Auricles:* small; anterior with two radiating cords; posterior wing larger and with a single cord; both auricles with incremental lines. *Hinge:* ligamental area broad. *Sculpture:* about 20 strong radiating ribs, the intercostal spaces of greater diameter and shallow; entire surface with fine concentric threads somewhat irregular in strength and width. *Color:* semitranslucent white.

This is a deep-water species which occurs at depths of 128 m.

L. hawaiana was described from the Hawaiian Islands.

Lima keokea Dall, Bartsch, and Rehder, 1938. Fig. 172 G, H. Height, 16 mm; length, 10 mm; diameter, 5 mm. *Shell:* ovate, compressed, light and thin; ribs threadlike, on the posterior slope only and with microscopic concentric threads; cream. *Auricles:* small; anterior projecting at its dorsal margin as a sharp point; with incremental lines. *Hinge:* ligamental area deeply excavated in the middle and projecting as a sharp point. *Sculpture:* central portion almost devoid of radiating ribs which occupy the shoulder of the posterior slope; surface marked with numerous closely approximated concentric threads. *Color:* cream or chalky white.

This is the most common of the Hawaiian limas; the animals are found on old coral blocks in shallow water in nests of loosely spun threads.

L. keokea was described from the Hawaiian Islands.

Lima lahaina Dall, Bartsch, and Rehder, 1938. Fig. 172 C, D. Height, 19 mm; length, 15 mm; diameter, 5 mm. *Shell:* trapezoidal, inflated, light and thin; ribs narrow with wide, shallow interspaces and microscopic concentric threads; white. *Auricles:* anterior ear with six radiating ribs, posterior with three. *Hinge:* ligamental area moderately broad, triangular with a few longitudinal grooves. *Sculpture:* slender radiating ribs which become lamellar basally, occasionally with interstitial threads; concentric sculpture of microscopic lirations which render the axial ribs serrulate; intercostal spaces wide, shallow, and deep. *Color:* white.

This is a rather uncommon species which occurs at depths of from 25 to 86 m.

L. lahaina was described from the Hawaiian Islands.

Lima parallela Dall, Bartsch, and Rehder, 1938. Fig. 172 F. Height, 8 mm; length, 4 mm; diameter, 3 mm. *Shell:* ovate, anterior and posterior margins parallel, compressed, light and thin; with slender radiating riblets and wider spaces crossed by fine, concentric threads; white. *Auricles:* small, with incremental lines only. *Hinge:* ligamental area rather broad. *Sculpture:* major portion of shell with 24 threadlike radiating riblets which develop into lamellae basally; interspaces much wider than the ribs; ribs and spaces crossed by fine, concentric threads; posterior and lateral sides with growth lines only. *Color:* translucent white.

Valves of *L. parallela* are rare, dredged at depths of 200 m.

L. parallela was described from the Hawaiian Islands.

Superfamily OSTREACEA

Family **Ostreidae**

The oysters are perhaps the most famous of all bivalves, beloved by gourmets, lyricized by poets, and cursed by systematists. Sedentary and cemented to hard objects, their flattened, distorted shells take on almost as many shapes as there are substrates to which they become attached.

Oyster shells are inequivalve, somewhat inequilateral, and usually have inconspicuous beaks. The left (lower) valve which is generally larger than the right valve, is convex, and cuplike; the right valve tends to be flat. The hinge line lacks teeth in the adult, but there are small teeth present in the prodissoconch. There is a single adductor muscle scar with its center posterior to the midline.

All oysters were at one time included in the genus *Ostrea* but those known to be dioecious are now included in the genus *Crassostrea*. The indigenous Hawaiian oysters are all apparently referable to *Ostrea*, with symmetrical valves, short hinge, and central white muscle scar. The species assigned to *Ostrea* usually live totally submerged in saline waters free from turbidity; they produce relatively few eggs that are fertilized and developed in the mantle cavity. In *Crassostrea* the attached valve is usually larger than the right, the prodissoconch is short, and the muscle scar is colored and eccentric. The habitat of most species of *Crassostrea* is in estuarine waters or in marine waters with considerable turbidity and low salinity; they produce enormous numbers of very small eggs which are fertilized and develop externally.

Crassostrea gigas (Thunberg, 1793). Fig. 173 H. Height, 170 mm; length, 60 mm. *Shell:* adherent, markedly inequivalve, elongate; lower valve deep, cup-shaped, recessed under the hinge; upper valve flat; beaks broadly oval but distorted; lamellae coarse and concentric; dirty white or gray; muscle scar faint purple. *Hinge:* without teeth in adult. *Sculpture:* coarse and widely spaced concentric lamellae or flutings and ridges. *Color:* exterior dirty white or gray; interior enamel white, often chalky, usually with a pale purple but extensive muscle scar and with greenish stains near the edge.

C. gigas is abundant in Kaneohe Bay, Oahu, where it grows attached to pilings, cement walls and coral heads in the intertidal zone. It was introduced into Hawaiian waters in 1926 at Kalihi, Oahu, and in 1939 seed oysters were planted in Kaneohe Bay (Brock, 1960). Oyster growth is continuous throughout the year, and experimental

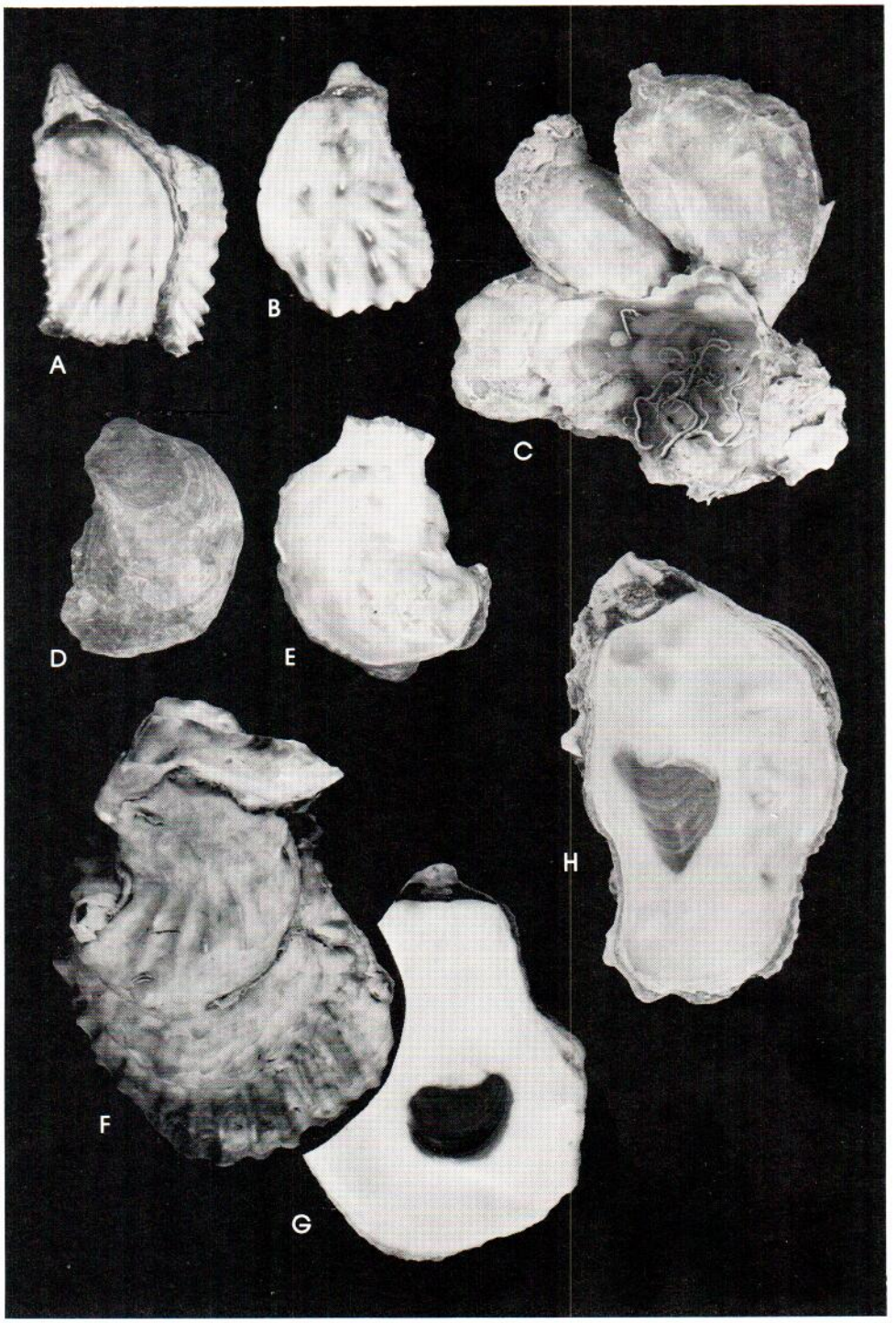


Figure 173.—**Ostreidae.** A, B. *Ostrea sandvicensis*, height 49 mm (type). C. *O. lima*, diameter of mass of shells 30 mm. D, E. *O. hanleyana*, height 40 mm (type). F, G. *Crassostrea virginica*, height 75 mm. H. *C. gigas*, height 170 mm.

studies indicate that approximately 14 months would be required to produce an oyster of marketable size (= 3 inches) (Brick, 1970). A flatworm, *Stylochus*, preys on the oysters in Kaneohe Bay (Edmondson, 1946a; Brick, 1970).

This oyster is a native of the Japanese islands of Hokkaido, Honshu, and Kyushu, and is cultured as a major food source both in the Orient and the United States.

Crassostrea virginica (Gmelin, 1791). Fig. 173 F, G. Height, 75 mm; length, 50 mm. *Shell:* broadly oval, solid; lower valve convex, upper valve flat; beaks and umbones not prominent; with concentric ridges and lines; white or dirty gray; muscle scar dark purple. *Hinge:* ligament internal, attached to a central, triangular pit with lateral extensions; adult without teeth. *Sculpture:* concentric ridges and lines, occasionally with radiating ribs on the left valve. *Color:* exterior white or dirty white or gray, sometimes with dark purple; interior white, the adductor muscle scar near the posterior margin and deep purple or red-brown.

There are some 150,000 square yards of major beds of *C. virginica* in Pearl Harbor, with an estimated 35,657,400 live oysters ranging in density from 67 to 406 oysters per square yard (Sparks, 1962). Absence of spat below 5 mm, the scarcity of small oysters, and gonadal studies during investigations in March, 1962, suggest seasonal spawning during the late spring or summer (Sparks, 1962). All the Hawaiian oysters examined were infested with a larval tapeworm, *Tylocephalum* (Sparks, 1963).

C. virginica, the American or Blue Point oyster, is native to the east coast of North America where it occurs from the St. Lawrence to the Gulf of Mexico and the West Indies. This species was probably first introduced into Hawaiian waters in 1866, and transplants have been made on a recurring basis since by both private concerns and government agencies.

Additional Introductions

Oysters introduced into Hawaiian waters but which have not become established include the Australian oyster *C. commercialis* (= *C. cucullata*, Edmondson and Wilson, 1940) planted in Kaneohe Bay, Oahu; the rock oyster *C. amasa* (= *Ostrea mordax)* (Brock, 1960) also planted in Kaneohe Bay; and the olympic oyster, *Ostrea lurida*, brought into the Islands in 1893 (Brock, 1960).

Ostrea hanleyana Sowerby, 1871. Fig. 173 D, E. (Synonym: *Ostrea thaanumi* Dall, Bartsch, and Rehder, 1938.) Height, 44 mm; length, 27 mm. *Shell:* oval, compressed and encrusting, irregular, solid; fluted; dirty white. *Hinge:* short; without teeth in adult. *Sculpture:* outer edge foliaceous and fluted; marginal pits and denticles merely indicated. *Color:* exterior creamy white or rayed with brown; interior white, often with vinaceous stains.

O. hanleyana is a common species subtidally under rocks on the outer edges of basalt tide-pool systems and on reefs. Fossil shells occur in an emerged Pleistocene reef near Barbers Point, Oahu (Dall, Bartsch, and Rehder, 1938, as *O. thaanumi*).

O. hanleyana was described from the Hawaiian Islands; Hedley (1899) records the species from the Ellice Islands, and it is also found at Fanning Atoll in the Line Islands (Kay, 1971).

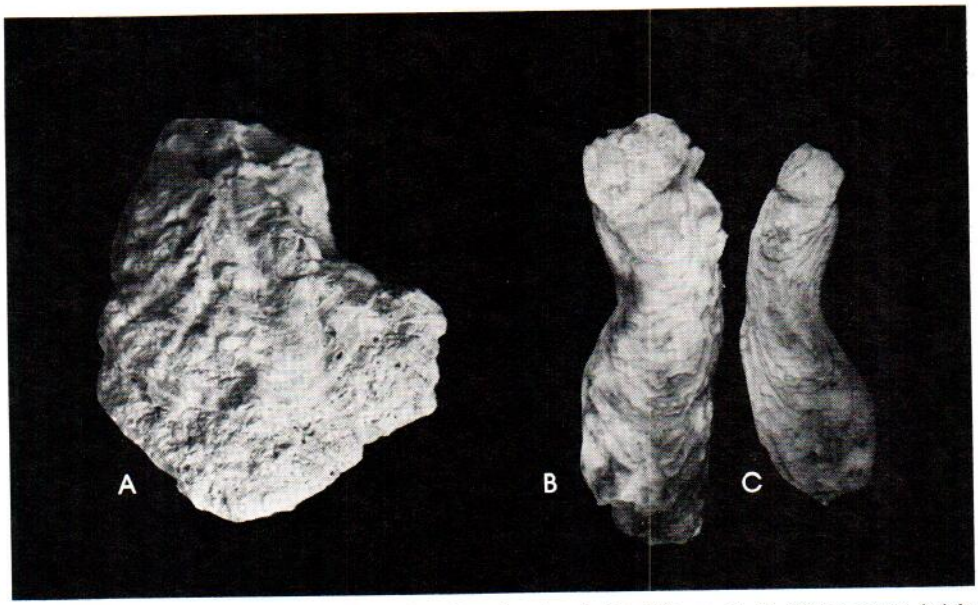


Figure 174.—Fossil oysters. A. *Pycnodonta kamehameha*, height 200 mm. B, C. *Ostrea retusa*, height 58 mm (type specimens, British Museum (Natural History)).

Ostrea laysana Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 59 mm; length, 42 mm. *Shell:* oval, thin-shelled; lower valve deeply cupped, upper valve concave; sculpture of obsolete folds; dirty white or gray. *Hinge:* with a median depression and transverse growth lines, extending as a narrow shelf over body cavity. *Sculpture:* lower valve with a few ill-defined, broad, low radiating folds; outer edge somewhat scalloped, with the merest indication of pits on the inner edge near the hinge; both valves with concentric growth lines. *Color:* yellow-white.

This is a deep-water oyster; the types were dredged by the *Albatross* at depths of 40 to 60 m off Laysan, and specimens have since been dredged at depths of 200 m off Oahu.

O. laysana was described from the Hawaiian Islands.

Ostrea lima Sowerby, 1871. Fig. 173 C. (Synonym: *Ostrea kauaia* Dall, Bartsch, and Rehder, 1938.) Height, 19 mm; length, 15 mm. *Shell:* oval, thin-shelled; lower valve deeply cupped; with fine concentric lamellae; dark red-brown. *Hinge:* short, triangular, bent to the left and with a median groove. *Sculpture:* lower valve with strong radiating keels crossed by low, concentric lamellae which frequently project as foliations; outer edge of shell strongly scalloped and developed as "clasping organs"; with coarse denticles on either side of hinge. *Color:* buff or red-brown, often with a rosy tinge.

This is a deep-water oyster; valves were dredged by the *Albatross* at depths of 554 to 624 m and have since been dredged by the *Pele* at 200 m. The "clasping organs" suggest the oyster lives attached to gorgonids or other slender, sedentary organisms.

O. lima was described from the Hawaiian Islands.

Ostrea sandvicensis Sowerby, 1871. Figs. 158 C; 173 A, B. (Synonyms: *Ostrea rosacea* Chemnitz, Bryan, 1915; *O. kupua* Dall, Bartsch, and Rehder, 1938.) Height, 49 mm; length, 20 mm; diameter, 8 mm. *Shell:* leaf-shaped to oval, moderately thick-shelled; lower valve deep, strongly beaked and fluted, upper valve almost flat, fluted; white. *Hinge:* central portion with a slight depression and with transverse growth lines; lower valve hollow below hinge. *Sculpture:* radiating, well-developed rounded ribs increasing in number by bifurcation and intercalation, the interspaces of about equal diameter; outer edge of valves scalloped, and with pits and denticles on the margin. *Color:* exterior white sometimes with dark purple radiations; interior greenish-white.

These oysters grow in clusters on rocks and pilings at Pearl Harbor and are a dominant element on the reefs in Kaneohe Bay and Ala Moana, Oahu. They are also common in brackish water habitats on Hawaii. Polyclads of the genus *Stylochus* are often found in association with the oysters but there is no direct evidence of predation (Poulter, 1963).

O. sandvicensis was described from the Hawaiian Islands.

Fossil Records

Fossil oysters are found in abundance in Pleistocene deposits on Oahu. *Pycnodonta kamehameha* (Pilsbry, 1936) (Fig. 174 A) (synonym: *Ostrea bryani* Pilsbry, 1918 non *O. bryani* Gabb, 1876) has a large (height, 210 mm), ponderous shell sculptured by strong radial ridges and with the beak occupying nearly half the total length of the shell; these oysters have been found in emerged reefs near Waianae and at Black Point, Oahu (and see Weaver, 1964b). *O. retusa* Sowerby, 1871 (Fig. 174 B, C) has a smaller shell (height, 58 mm; length, 149 mm) which is elongate and tongue-shaped, with a moderately cupped lower valve and slightly concave upper valve. These oysters occur in a single fossil bed near Pearl Harbor, Oahu; the bed was first described by Couthouy (1844) during the visit of the United States Exploring Expedition. *O. margaritae* Pilsbry, 1918, also occurs in fossil beds near Pearl Harbor, Oahu; it resembles *O. sandvichensis* but is distinguished by its lack of sculpture and long beaks.

Superfamily CHAMACEA

Family **Chamidae**

The chamas or rock oysters are sedentary bivalves. The right valve is uppermost, larger and thicker than the left and covered with encrusting coralline growths and worm tubes; the left valve is flat and cemented to the substrate. The ligament is external, placed in a deep groove along the hinge plate; the hinge plate is solid, and there are strongly projecting teeth on the left valve which fit into deep grooves on the right valve. There is a single large, reticulated muscle scar; the pallial line is entire.

On the Great Barrier Reef chamas are said to be unfit for eating, causing a form of dysentry (Rippingale and McMichael, 1961), but pre-Western Hawaiians apparently used them for food.

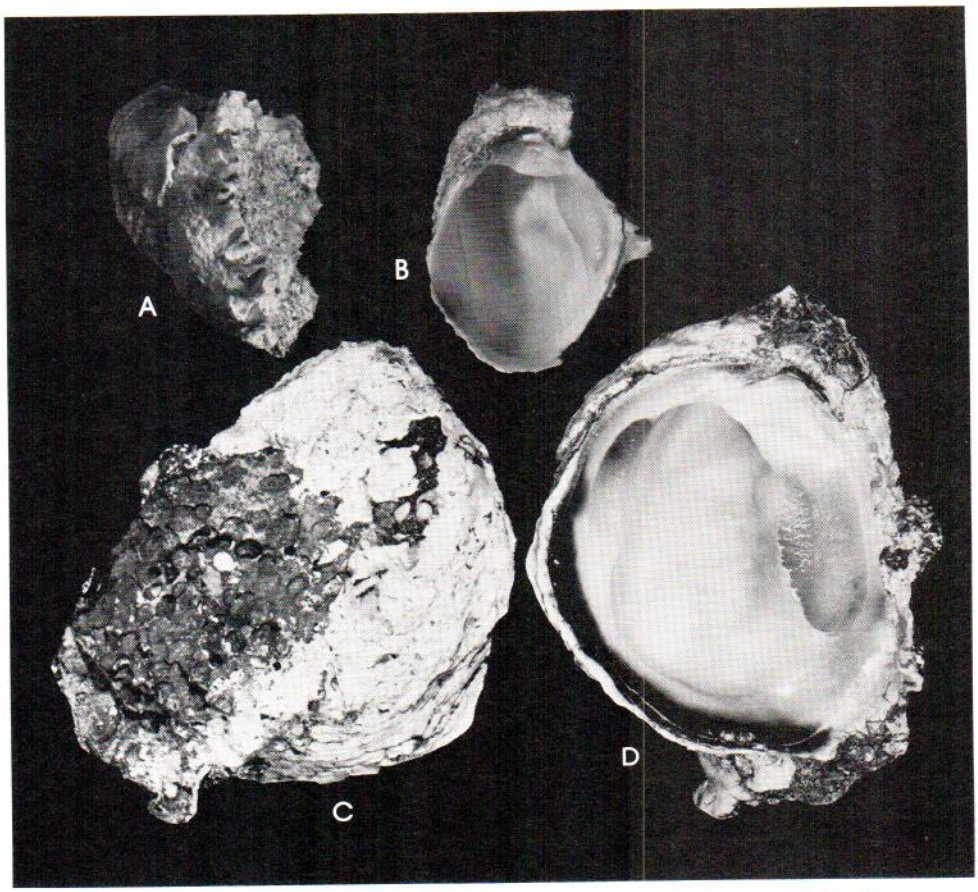


Figure 175.—**Chamidae.** A, B. *Chama fibula*, height 12 mm. C, D. *C. iostoma*, height 72 mm.

Chama fibula Reeve, 1846. Fig. 175 A, B. (Synonym: *Chama hendersoni* Dall, Bartsch, and Rehder, 1938.) Height, 12 mm; length, 16 mm; diameter, 14 mm. *Shell:* orbicular, solid; lower valve twisted and inner edge finely denticulate, upper valve convex and with rows of short spines; white. *Hinge:* ligament moderately broad and curved; hinge with a strong, median, foldlike tooth which is vertically laminated and with a strong curving fold; right valve with a fold fitting between the two elements of the lower valve. *Sculpture:* upper valve with closely spaced lamellae forming scallops and spines; lower valve lamellae. *Color:* white.

This is an uncommon bivalve among the windward islands, and all specimens recorded have been found either in Pearl Harbor or Honolulu Harbor, Oahu. *C. fibula* is, however, very common in beach drift at Midway.

There seems no reason to distinguish the Hawaiian shells from the Pacific species. *C. fibula* was described from the Philippines, and was recorded from Sydney Harbour, New South Wales, Australia (Hedley, 1916).

Chama iostoma Conrad, 1837. Fig. 175 C, D. Height, 72 mm; length, 67 mm; diameter, 40 mm. *Shell:* subcircular but often irregular, solid; left valve thin and

attached to the substrate, right valve thick and concave; with concentric lamellae covered by heavy incrustations; interior white, edged with purple. *Hinge:* ligament strongly curved; hinge of lower valve with a broad, oblique fold and a deep tooth; upper valve with a projection fitting between tooth and fold of lower valve, folds and teeth finely denticulated. *Sculpture:* upper and lower valves with concentric lamellae, somewhat scalelike in the upper valve and forming attachment abutments in the lower valve. *Color:* exterior gray with encrusting coralline growths; interior porcelaneous white, the outer border edged with purple.

This is a common shallow-water species often found on rocks and benches exposed to surf, in tide pools, and in waters shoreward of fringing reefs; shells have been dredged to depths of 100 m.

C. iostoma was described from the Hawaiian Islands but is widespread in the Indo-West Pacific, reported from the Great Barrier Reef (Rippingale and McMichael, 1961) and the Amami Islands (Kira, 1962).

Superfamily LUCINACEA

Family **Lucinidae**

The lucinids are easily distinguished by their subcircular, equivalve shells most of which have clearly differentiated, vertically arranged cardinal teeth and horizontally disposed lateral teeth. The tooth projections on one valve fit into sockets in corresponding positions on the opposite valve. The ligament is usually external, attached to a deeply immersed scar lying below the margin of the valve. There are two adductor muscle scars of unequal size, the anterior scar usually larger and divided; the pallial line is entire and there is no pallial sinus. The shells are sculptured with radial or concentric elements or a combination of both, and there is sometimes a scaly periostracum.

These bivalves are typically infaunal organisms, living in a variety of substrata from sand to mud, where they burrow to a depth about equal to the length of the vermiform foot.

Codakia punctata (Linnaeus, 1758). Fig. 177 C, D. (Synonym: *Codakia thaanumi* Pilsbry, 1918.) Height, 53 mm; length, 55 mm; diameter, 27 mm. *Shell:* subcircular, compressed; beaks curving anterior to the midline; radiating ribs broad and flat; white. *Hinge:* lunule heart-shaped; ligament broad with two obliquely raised ridges; hinge with two cardinals, an anterior knoblike lateral and a weak posterior lateral tooth in the right valve and two cardinals, a weak lateral posteriorly and two laterals anteriorly in the left valve. *Sculpture:* prodissoconch smooth, remainder of valves with broad, flat radiating ribs, the interspaces of lesser diameter. *Color:* white.

These bivalves are rather uncommon in shallow water and to depths of 16 m. They occur as fossils in Pleistocene reefs on Oahu (Ostergaard, 1928).

Although Pilsbry (1918) distinguished the Hawaiian shells from the Indo-West Pacific species on the basis of their lack of a bright marginal band, greater convexity, stronger, narrower ribs, and more prominent beaks, these features appear so variable

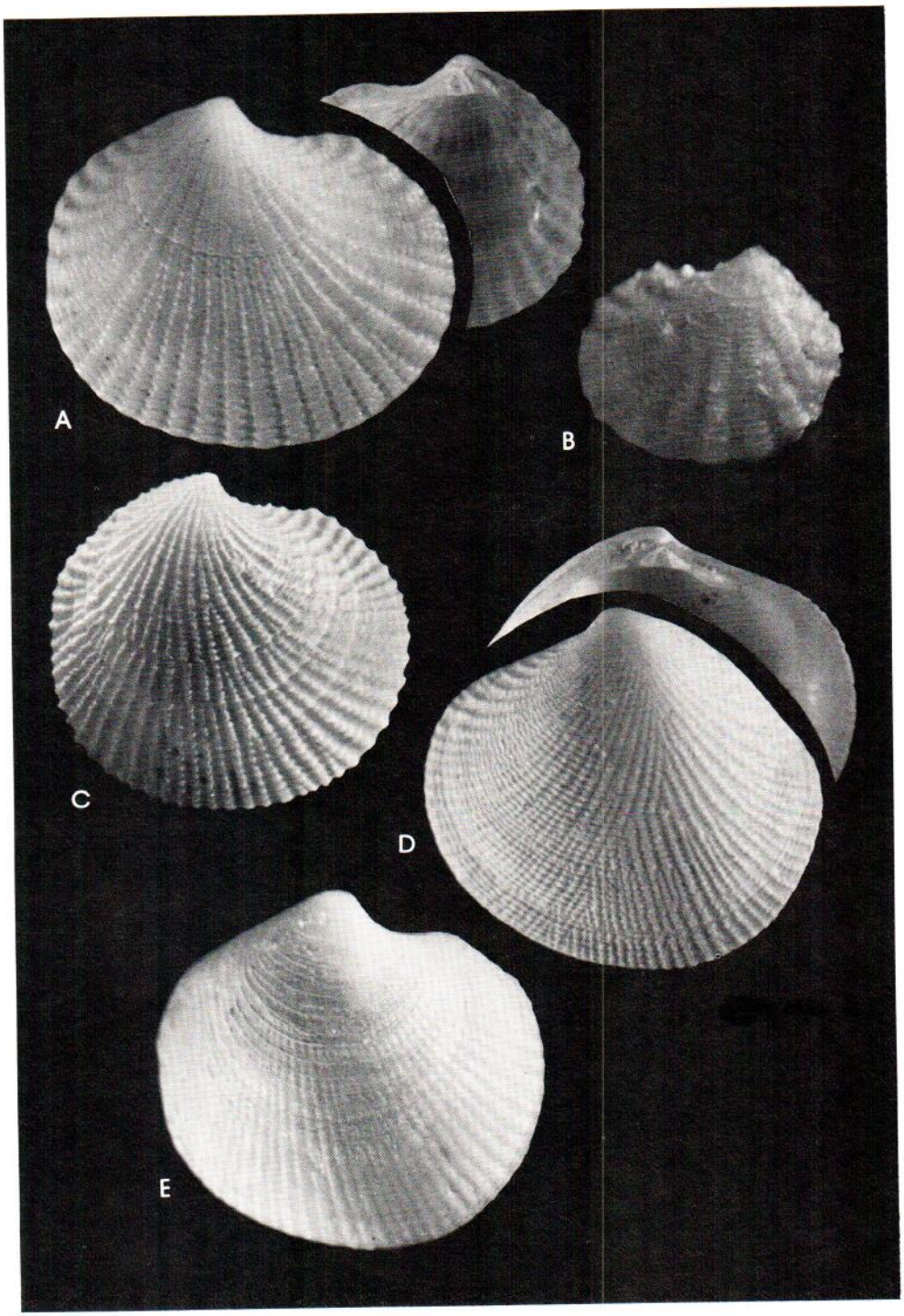


Figure 176.—**Lucinidae.** A - D. *Ctena bella*. A, height 24 mm. B, height 8 mm. C, height 20 mm. D, height 24 mm. E. *C. transversa*, height 10 mm.

as to invalidate the distinction. Shells from the windward islands in the Hawaiian chain usually lack a marginal color band, but those from Midway and Kure have the bright border seen in specimens from elsewhere in the Pacific. In addition to its wide range in the Indo-West Pacific, *C. punctata* has been recorded from Clipperton Island (Hertlein and Allison, 1966, as *C. thaanumi)*.

Ctena bella (Conrad, 1837). Fig. 176 A-D. (Synonym: *Codakia ramulosa* Gould, Bryan, 1915.) Height, 23 mm; length, 25 mm; diameter, 13 mm. *Shell:* subcircular; beaks anterior to midline and moderately projecting; anterior margin strongly curved and projecting more than the flattened posterior; faintly nodulose radiating ribs crossed by concentric threads; usually white. *Hinge:* lunule moderately impressed and elongate-oval; ligament about half the length of the posterior dorsal margin and deeply inset; hinge with two cardinal teeth, posterior in right and anterior in left valve bifid, and an anterior and posterior lateral. *Sculpture:* variable — basically with radiating ribs crossed by concentric lamellar threads but with the ribs dividing in some shells (Fig. 176 D), the concentric sculpture pronounced and almost ruffled in juvenile valves (Fig. 176 B) but rather flat in other valves (Fig. 176 A). *Interior:* anterior muscle scar smaller than posterior; margin crenulate. *Color:* usually white, occasionally pink or yellow in shallow water.

These bivalves are ubiquitous, common in shallow water in sandy tide pools, on sand patches, and in sandy pockets on fringing reefs, and valves have been dredged from depths of more than 60 m. The shallow-water shells tend to have a rather subdued sculpture, the deeper water shells tend to be more nodular (Fig. 176 C, D). This species is recorded as a Pleistocene fossil on Oahu (Ostergaard, 1928 as *Jagonia bella*).

C. bella was described from California but Conrad's (1837) specimens were collected by Thomas Nuttall in the Hawaiian Islands. The species is widespread in the Indo-West Pacific and is also recorded from the Kermadec Islands (Oliver, 1915).

Ctena transversa Dall, Bartsch, and Rehder, 1938. Fig. 176 E. Height, 9 mm; length, 10 mm; diameter, 5 mm. *Shell:* subcircular, slightly inflated; beaks anterior to the midline and prominent; anterior and posterior margins rounded; with broad, low radial ribs crossed by concentric lamellar threads; cream. *Hinge:* lunule shallow, ovate; ligament external; hinge with two cardinals in each valve, anterior in right and posterior in left bifid, cardinals separated by a deep pit and strong, triangular, foldlike laterals. *Sculpture:* prodissoconch smooth; low, rounded, broad radiating ribs crossed by slender, closely spaced lamellae which bend ventrally and render ribs feebly nodulose. *Interior:* anterior muscle scar longer and narrower than posterior; pallial line entire; margin crenulate. *Color:* cream to yellow-white with a brown tint; interior yellow-white.

C. transversa occurs at depths of from 8 to 100 m.

This species was described from the Hawaiian Islands.

Lucina edentula (Linnaeus, 1758). Fig. 177 A, B. (Synonyms: *Diplodonta globosum* Forskål, Edmondson, 1933; *Loripinus hawaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 21 mm; length, 23 mm; diameter, 15 mm. *Shell:* subglobular, thin,

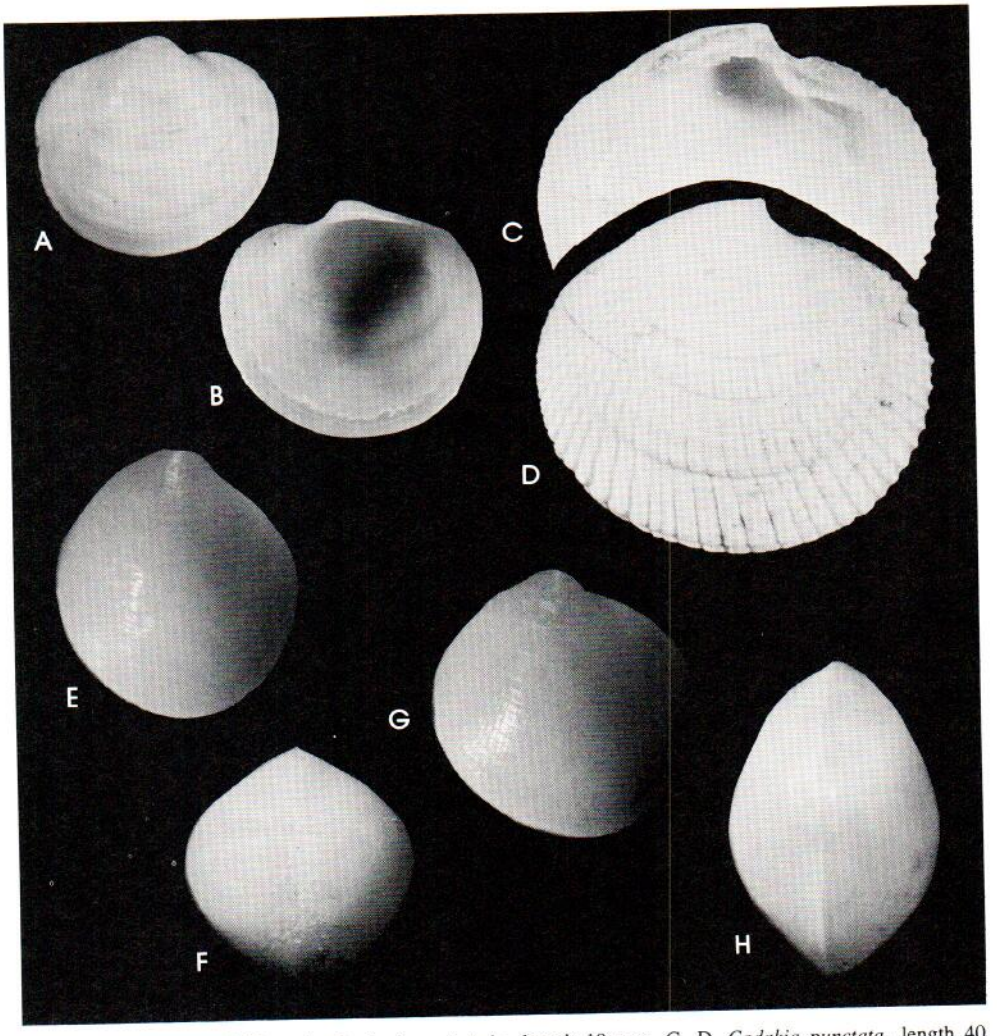


Figure 177.—**Lucinidae.** A, B. *Lucina edentula,* length 18 mm. C, D. *Codakia punctata,* length 40 mm. E, F. *Pillucina spaldingi,* height 7 mm (E); dorsal view diameter 6 mm (F). G, H. *P. hawaiiensis,* height 5 mm (G), dorsal view diameter 5 mm (H).

inflated; equilateral, beaks stout; with concentric growth lines and microscopic radiating striae; yellow-white. *Hinge:* ligamental area hidden by dorsal shelf; no teeth on the hinge. *Sculpture:* prodissoconch smooth; remainder of valves with growth lines and microscopic radiating striae. *Color:* yellow white.

L. edentula occurs at depths of from 8 to 198 m; shells are abundant in beach drift on Midway.

Although the Hawaiian shells were distinguished as a separate species by Dall, Bartsch, and Rehder (1938), they differ from the widespread Indo-West Pacific species only in their consistently smaller size. *L. edentula* has been recorded from the east coast of Africa and through the Indian and Pacific oceans (Lynge, 1909; Prashad, 1932).

Pillucina hawaiiensis (Smith, 1885). Fig. 177 G, H. Height, 6 mm; length, 8 mm; diameter, 5 mm. *Shell:* subcircular, inflated; beaks anterior to midline; margins rounded; radiating ribs crossed by concentric lamellae; white. *Hinge:* lunule small, deeply impressed; left valve with two cardinals, the anterior larger, separated by a pit into which fits the single strong cardinal of the right valve; anterior and posterior laterals of both valves very small. *Sculpture:* prodissoconch smooth; with radiating ribs crossed by concentric, sublamellar cords, nodulose at their junctions with the ribs. *Interior:* pallial line deep within shell; margins crenulate. *Color:* white.

P. hawaiiensis occurs at depths of from 12 to 20 m.

This species was described from the Hawaiian Islands.

Pillucina spaldingi (Pilsbry, 1921). Fig. 177 E, F. Height, 9 mm; length, 8 mm; diameter, 7 mm. *Shell:* elongate-ovate, moderately inflated; beaks posterior to midline; dorsal margin short, moderately curved, anterior edge less curved than posterior; with broad, low concentric cords and radiating threads; white. *Hinge:* lunule short, broad, strongly impressed; left valve with two diverging cardinals and low, obsolescent laterals; right valve with a strong cardinal tooth and two depressions on either side, beyond which are the laterals. *Sculpture:* prodissoconch smooth; feeble, low, broad concentric cords with radiating threads between. *Interior:* pallial line deep within shell and the margin thickened; margins crenulate. *Color:* white.

Only a few specimens of this species are known; Pilsbry's type was collected in Kaneohe Bay, Oahu.

P. spaldingi was described from the Hawaiian Islands.

Superfamily LEPTONACEA
(= ERYCINACEA, GALEOMMATACEA)

This family comprises small bivalves (most are less than 10 mm in length), many of which live as commensals on larger burrowing invertebrates such as echinoderms, worms, and crustaceans (Boss, 1965b). The shells are rather featureless and hence difficult to distinguish, but the soft parts exhibit several features which are unique among bivalves. In some the mantle almost covers the valves, in others the foot may be extremely long and flexible with a resulting array of postures and movements. Families have been separated on the basis of the presence or absence of an outer demibranch on the gills, but Ponder (1971) suggests that loss of the outer demibranch may be associated with the incubation of larvae, a feature distinctive among the Leptonacea and which perhaps enables some of them such as *Lasaea* to live in the intertidal zone. The arrangement of families followed here is that of Ponder (1971) rather than Chavan (1969).

Family **Lasaeidae**

This family of small bivalves includes a variety of forms, various members of which have been separated in several families such as the Montacutidae and Kelliidae (see Chavan, 1969). Although the group includes a variety of shell shapes and there are differences in the structure and development of the demibranchs, Ponder (1971)

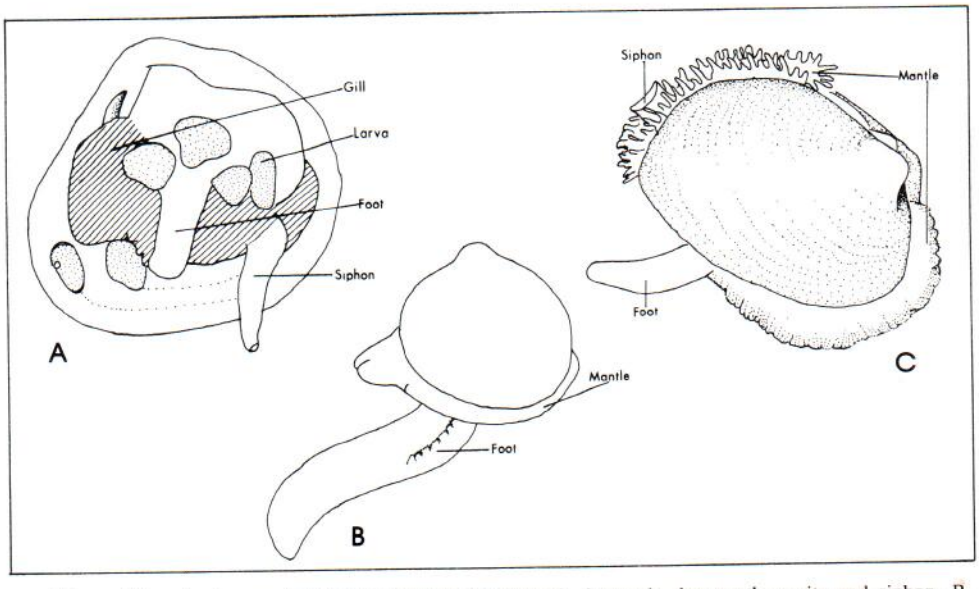


Figure 178.—A. *Lasaea hawaiensis* showing demibranch, larvae in the mantle cavity and siphon. B. *Kellia hawaiensis* with foot extended. C. *Anisodonta angulata* with mantle and siphon extended. (By R. Kawamoto.)

suggests there are no basic anatomical differences among the animals of *Lasaea, Kellia, Montacuta,* etc. that would justify separating them in different families.

The shells of members of the family are small (1 mm to about 12 mm in Hawaii), ovate to elliptical, and usually smooth and glossy. The hinge plate is indented under the beaks and there are usually cardinal and lateral teeth in both valves.

Kellia hawaiensis Dall, Bartsch, and Rehder, 1938. Figs. 178 B; 179 C. Height, 4 mm; length, 5 mm; diameter, 3 mm. *Shell:* suborbicular, inflated, thin; inequilateral, beaks anterior to the midline; surface smooth; translucent, glassy white. *Margins:* beaks prominent; anterior and ventral margins slightly curved, posterior margin straight. *Hinge:* external ligament thin, resilium rather short, in an oblique groove; hinge in right valve with a strong, erect cardinal tooth, a small, low triangular tooth on the margin parallel to it, and a short, sublamellar posterior lateral; left valve with a projecting hook-like cardinal, another diverging, short cardinal anterior, and a short, low triangular posterior lateral. *Sculpture:* incremental growth lines only. *Color:* glassy white. *Animal:* white; foot long, narrow, and extremely extensible — to a length of 10 mm for a 12 mm shell. Three pallial openings, the anterior an elongate siphon, a ventral pedal opening, and a posterior exhalent opening in the form of a short siphon.

These bivalves occur at depths of 2 to 60 meters and are found in bivalve shells as is reported for species of *Kellia* in California (Yonge, 1952).

K. hawaiensis was described from the Hawaiian Islands.

Kellia (Kaneoha) rosea (Dall, Bartsch, and Rehder, 1938). Fig. 179 B. Height, 1 mm; length, 1 mm; diameter, 0.5 mm. *Shell:* suborbicular, moderately inflated, thin; inequilateral, beaks just anterior to the midline; surface smooth; rose-colored. *Margins:*

beaks prominent; anterior end somewhat more attenuated and convex than posterior. *Hinge:* resilium short, stout, attached to the dorsal margin by an oblique groove; hinge in right valve with an erect, triangular cardinal tooth, often with a rather obsolete tubercle at the base and a long, posterior lateral; left valve with an anterior cardinal projecting into the interior, a longer posterior cardinal parallel to the margin, and a long, narrow posterior lateral. *Sculpture:* smooth except for fine, concentric incremental lines. *Interior:* adductor muscle scars about equal, pallial line wide, without a sinus, margin smooth. *Color:* rose, becoming white toward the umbo.

These bivalves occur in shallow water, nestled in the byssus of mytilids and *Isognomon* and at the base of algae such as *Laurencia*.

K. rosea was described from the Hawaiian Islands.

Kona symmetrica (Pilsbry, 1921). Fig. 179 K. Height, 2 mm; length, 2.7 mm. *Shell:* ovate, moderately inflated, moderately thin; beaks nearly terminal; glassy white. *Margins:* beaks prominent; ventral margin slightly more convex than the dorsal margin. *Hinge:* resilium stout, thick, lying in a groove in a perpendicular shelf, lamellar tooth long, cardinals degenerate. *Sculpture:* smooth except for fine, obscure growth lines. *Interior:* muscle scars unequal, dorsally slightly impressed, anterior elongate, posterior suborbicular; pallial line simple. *Color:* glass white.

These bivalves live in shallow water and valves are occasionally found in sediments to depths of 10 m.

Kona symmetrica was described from the Hawaiian Islands. The shells superficially resemble those of *Nucula hawaiensis* but are distinguished by the hinge line which lacks the taxodont dentition of *Nucula*. A second species of *Kona, K. bucki* Dall, Bartsch, and Rehder, 1938, was described from a single valve and distinguished from *K. symmetrica* by its attenuate posterior end.

Lasaea hawaiensis Dall, Bartsch, and Rehder, 1938. Figs. 178 A; 179 A. (Synonym: *Lasaea rubra* Montagu, Edmondson, 1933.) Height, 3 mm; length, 4 mm; diameter, 3 mm. *Shell:* ovate to suborbicular, inflated, inequilateral; beaks posterior to midline; surface with concentric growth lines; red-brown. *Margins:* beaks large and prominent; ventral margin convex; anterior edge more convex than posterior. *Hinge:* resilium stout, broad, in a groove on a shelflike projection from the hinge; without prominent cardinal teeth; lateral teeth forming a complex on each side. *Sculpture:* fine, concentric growth lines and radial striae. *Interior:* adductor muscle scars about equal; pallial line without a sinus; margin smooth. *Color:* exterior yellow to red-brown and tinged with darker red-brown toward the beaks; interior white, hinge and dorsal margin purple-red.

These bivalves are found nestled among the byssal threads of *Isognomon californicum* and in the holdfasts of the algae *Rosenvingia* and *Ahnfeltia* on surf-swept coastlines. The young are incubated in the mantle cavity to a stage where they can crawl.

L. hawaiensis was described from the Hawaiian Islands. Several malacologists have pointed out difficulties in separating the nominal form of *Lasaea, L. rubra* (Montagu, 1803), which is regarded as European and Mediterranean in distribution, from forms found in South Africa and the southern Atlantic. Ponder (1971) suggests that the several species described from California, Japan, New Zealand, and Hawaii may be only regional subspecies of the nominal form.

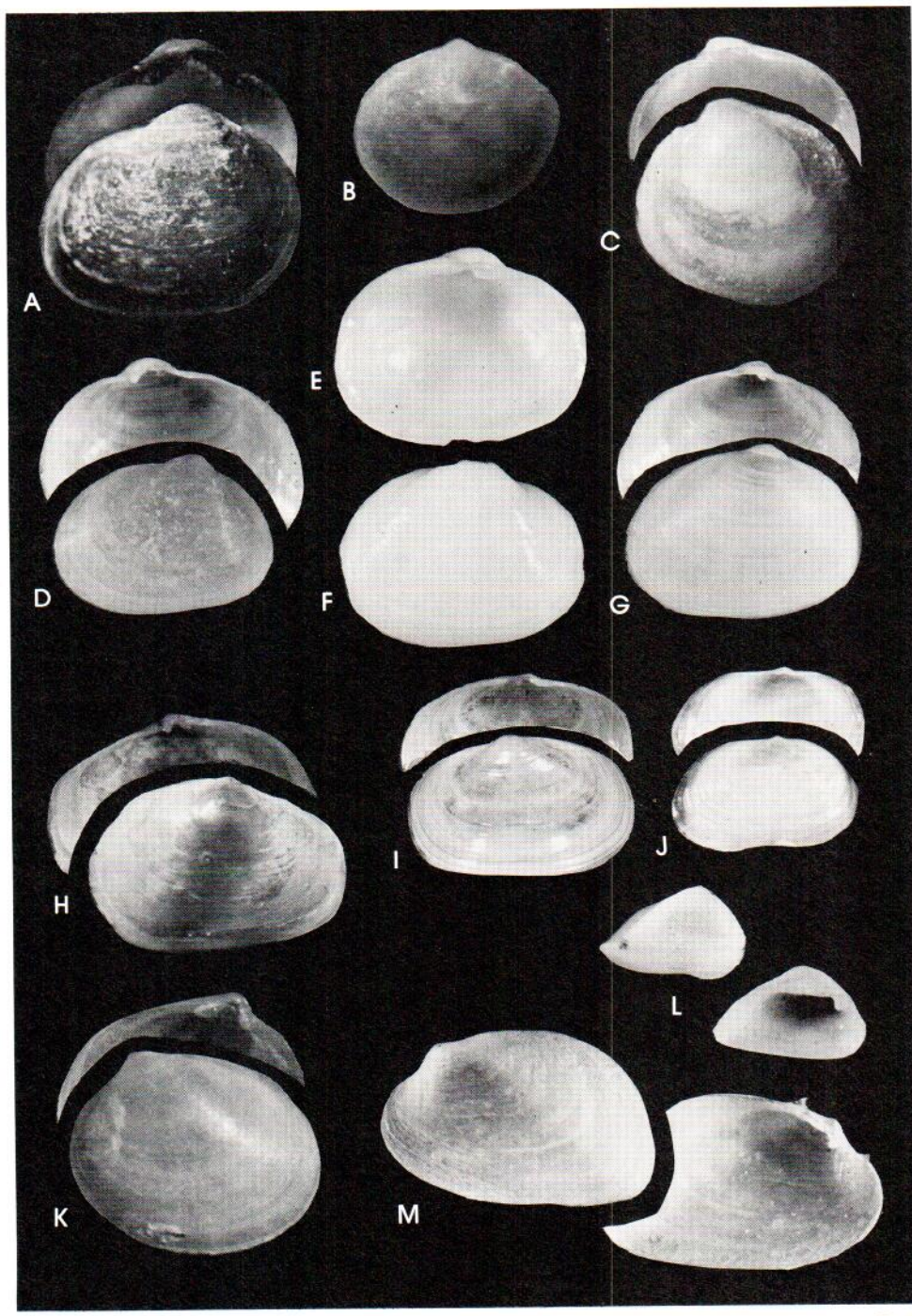


Figure 179.—**Lasaeidae.** A. *Lasaea hawaiensis*, length 3 mm. B. *Kellia rosea*, length 1 mm. C. *K. hawaiensis*, length 5 mm. D. *Radobornia bryani*, length 11 mm. E, F. *Hitia ovalis*, length 10 mm. G. *Nesobornia bartschi*, length 7 mm. H. *Scintillona stigmatica*, length 8 mm. I. *Scintilla hiloa*, length 8 mm. J. *Leiochasmea elongata*, length 7 mm. K. *Kona symmetrica*, length 3 mm. L. *Anisodonta angulata*, length 10 mm. M. *A. lutea*, length 6 mm.

Nesobornia bartschi Chavan, 1969. Fig. 179 G. (Synonyms: *Erycina ovata* Gould, 1850, non Gray, 1825; *Solecardia hawaiiensis* Pilsbry, 1921; *S. hawaiiensis obesior* Pilsbry, 1921.) Height, 9 mm; length, 12 mm; diameter, 7 mm. *Shell:* oval, inflated; equivalve; inequilateral, beaks anterior to the midline; smooth; glossy, white. *Margins:* beaks barely projecting; ventral margin straight or convex; anterior and posterior margins curved. *Hinge:* external ligament posterior to umbo; interior ligament in a short, oblique groove posterior to dorsal margin; hinge of right valve with a prominent triangular cardinal tooth and a lamellar posterior cardinal; left valve with two subequal diverging cardinals and a short posterior lateral. *Sculpture:* concentric incremental lines only. *Color:* glossy, white.

This is one of the most common of small, shallow-water bivalves in Hawaiian waters. It is free-living, found in clusters of ten or twelve under rocks in tide pools, on solution benches, and in shallow water shoreward of fringing reefs. The animals are active, their elongate foot freely moving about the substrate and their movements sometimes simulate those of gastropods.

N. bartschi occurs throughout the Indo-West Pacific from the Seychelles to the Marshall and Line Islands in the Pacific.

Pilsbry (1921) and Dall, Bartsch, and Rehder (1938) distinguished the Hawaiian shells from the Gould species (also described from the Hawaiian Islands) because of their small size, straight ventral margin and lack of anterior cardinal tooth. The shells are variable, however, especially with respect to hinge structure, and there seems no reason to distinguish two species.

Radobornia bryani (Pilsbry, 1921). Fig. 179 D. (Synonym: *Radobornia araia* Dall, Bartsch, and Rehder, 1938.) Height, 9 mm; length, 11 mm; diameter, 6 mm. *Shell:* broadly ovate, somewhat inflated, thin and brittle; inequilateral, beaks anterior to midline; surface microscopically punctate; white. *Margins:* beaks moderately prominent; ventral and dorsal margins slightly curved. *Hinge:* external ligament thin, posterior, partly in conjunction with a darker resilium which is attached to an oblique groove; right valve with a strong hooklike cardinal with an obsolete dorsal tubercle; left valve with smaller hooklike cardinals; both valves with a posterior lateral. *Sculpture:* surface entirely punctate. *Color:* white.

These bivalves are known only from shells collected in beach drift except for specimens found by Thaanum at Keokea, Hawaii (Dall, Bartsch, and Rehder, 1938 as *R. araia*).

R. bryani was described from the Hawaiian Islands, but shells from Madagascar and the Maldives are indistinguishable from those from Hawaii. Habe (1977) records the species (as *R. bryoni* [*sic*]) from southern Japan north to Shikoku and Kii Peninsula, Honshu, and suggests *Nesobornia lactea* Kuroda, 1960, from the Ryukyu Islands is a synonym.

Family **Galeommatidae**

This family is unusual among the bivalves because in some species the mantle extends over the surface of the valves, often covering them almost completely. The shells are oblong-ovate, often scalelike, and the ventral margin usually gapes open. The surface is smooth, glossy, or covered with radial riblets. The hinge is usually

edentulous, but occasionally there may be small, weak cardinal teeth on the hinge. A number of species assigned to the family are free-living.

Leiochasmea elongata Preston, 1908. Fig. 179 J. (Synonym: *Leiochasmea chascax* Pilsbry, 1921.) Height, 4 mm; length, 7 mm; diameter, 2 mm. *Shell:* ovate to elliptical, moderately inflated, thin; equivalve; inequilateral, beaks barely projecting, anterior to midline; surface smooth and glossy; transparent white. *Margins:* anterior, posterior, and ventral edges curving; ventral margin gaping. *Hinge:* external ligament thin; resilium stout, short, in an oblique groove; hinge line without teeth. *Sculpture:* absent except for growth lines. *Color:* translucent, glassy white.

These bivalves have been collected in shallow water "on coral at Keokea, Hilo, Hawaii" (Dall, Bartsch, and Rehder, 1938) and at depths of 36 to 80 m off Oahu.

L. elongata was described from the Andaman Islands. *L. chascax* was described from Hawaii.

The genus *Leiochasmea* was erected for galeommatids with polished shells without either sculpture or teeth on the hinge (Dall, Bartsch, and Rehder, 1938). Olsson (1961) compares *Leiochasmea* with *Tryphomyax* from Panama which also has a smooth surface and edentulous hinge but which is characterized by a narrow, deep notch in the ventral margin.

Scintilla hiloa Dall, Bartsch, and Rehder, 1938. Fig. 179 I. Height, 8 mm; length, 13 mm; diameter, 6 mm. *Shell:* ovate, somewhat inflated, thin; equivalve; inequilateral, beaks anterior to the midline; surface smooth; white. *Margins:* beaks rather prominent; ventral margin almost straight. *Hinge:* ligament long and thin with a short, stout resilium posterior to the beak in a conspicuous groove; hinge line narrow; right valve with a tubercular cardinal and smaller posterior cardinal; left valve with a pointed triangular cardinal and smaller tuberculate anterior cardinal; posterior lateral in both valves low, long, slender. *Sculpture:* smooth except for incremental lines. *Color:* white. *Animal:* no definitive inhalent siphon but free edges of the mantle project beyond the shell forming a temporary siphon; two pallial openings with the mantle lobes fused between the pedal opening and the exhalent siphon. Free edge of mantle with tentacular papillae. Foot large, wedge-shaped.

These bivalves have been collected in shallow water at Keokea, Hawaii, and dredged at depths of 73 m off Oahu. They appear to be free-living.

S. hiloa has been reported only from the Hawaiian Islands.

Scintillona stigmatica (Pilsbry, 1921). Fig. 179 H. Height, 8 mm; length, 13 mm; diameter, 6 mm. *Shell:* ovate to subelliptical, somewhat inflated, thin; inequilateral, beaks anterior to midline; smooth; white blotched with brown. *Margins:* beaks barely prominent; ventral margin straight or slightly curved; anterior end narrower and more angular than posterior. *Hinge:* ligament long and thin with a short, stout resilium posterior to the beaks in a conspicuous groove; hinge line narrow; right valve with a tubercular cardinal and smaller posterior cardinal; left valve with a triangular cardinal and a smaller, tubercular anterior cardinal; posterior lateral in both valves long, low, lamellar. *Sculpture:* smooth, except for incremental lines. *Color:* white with a rich

red-brown elongate blotch running slightly posteriorly from the umbones to the margins; interior white with external color showing through.

These bivalves occur in shallow water on the sea urchin *Brissus latecarinatus* where they are found clustered near the anal opening.

S. stigmatica was described from the Hawaiian Islands and has also been found among the spines on the ventral surface of *Brissus latecarinatus* in Wakayama Prefecture, Honshu, Japan (Yamamoto and Habe, 1974).

Additional Record

Leiochasmea thaanumi (Pilsbry, 1921) is small (height, 4 mm; length, 7 mm), and has a moderately inflated, smooth white shell which does not gape at the ventral margin. The unique type is in the Academy of Natural Sciences of Philadelphia.

Superfamily CYAMIACEA

Family **Sportellidae**

The superfamily includes bivalves with small, thin shells of varying shape, equivalve but inequilateral, and with the beaks anterior to the midline. The most useful characters in determining relationships in the group are features of the hinge and anatomy. The hinge teeth occur in two series, an upper and a lower. The mantle has two openings in the posterior end.

Only the family Sportellidae is represented in Hawaiian waters. The shells are ovate, thin, and have prominent beaks. The ligament is external and the surface smooth. Like the leptons, sportellids appear to be commensal with larger invertebrates such as worms.

Anisodonta angulata Dall, Bartsch, and Rehder, 1938. Figs. 178 C; 179 L. Height, 3 mm; length, 6 mm; diameter of a single valve, 3 mm. *Shell:* rhomboidal, with a pronounced keel extending from posterior edge of umbo to junction of posterior and ventral margins; dorsal line straight; anterior edge evenly curved, posterior end slightly protracted, ventral margin slightly concave; surface with small tubercles; white. *Hinge:* with a single strongly projecting cardinal beneath the beak in each valve. *Interior:* anterior muscle scar larger than posterior; margins smooth. *Sculpture:* outer surface with fine growth lines and minute, irregular granulations. *Color:* white. *Animal:* white; foot of medium size; no byssal gland or groove. Mantle edge slightly scalloped anteriorly and ventrally, with about 24 well-developed tentacles on each side posteriorly near the inhalent and exhalent pallial apertures; inhalent opening with a short siphon. Inner demibranch large, occupying most of the pallial cavity; outer demibranch small.

These bivalves are found in the mud tube of a polychaete worm in tide pools, on benches and on fringing reefs.

A. angulata was described from the Hawaiian Islands.

Anisodonta lutea Dall, Bartsch, and Rehder, 1938. Fig. 179 M. Height, 4 mm; length, 6 mm; diameter, 2.4 mm. *Shell:* subquadrate with the dorsal and ventral margins almost parallel, inflated; slight ridge from umbo to posterior margin, anterior edge strongly curved, posterior margin slightly curved; surface with incremental growth lines; pale straw-colored. *Hinge:* ligament posterior to midline; hinge with a conspicuous hooklike tooth below the beak in the left valve. *Interior:* posterior muscle scar large; anterior muscle scar obsolete. *Sculpture:* prodissoconch with microscopic concentric threads; remainder of valves with fine, concentric growth striae. *Color:* pale straw.

Valves are common in drift but nothing is known of the habits of the living animals.

A. lutea was described from the Hawaiian Islands. The valves are distinguished from those of *A. angulata* by their lack of a keel and pale straw color.

Hitia ovalis Dall, Bartsch, and Rehder, 1938. Fig. 179 E, F. Height, 6.8 mm; length, 10.2 mm; diameter, 6 mm. *Shell:* ovate, inflated; equivalve; inequilateral; beaks anterior to the midline; smooth; white. *Margins:* beaks barely projecting; ventral margin gently convex; anterior and posterior margins equally convex. *Hinge:* external ligament thin; internal resilium short, lying in an oblique groove; hinge of right valve with a prominent triangular cardinal and a lamellar posterior lateral; left valve with two subequal diverging cardinals and a short posterior lateral. *Sculpture:* concentric incremental lines only. *Color:* polished white.

These bivalves are uncommon, dredged at depths of 50 meters.

The type specimens were collected by W. H. Pease in the "Sandwich Islands" and are in the U. S. National Museum, but the species was not subsequently recorded from the islands until about 1970.

Superfamily CARDITACEA

Family **Carditidae**

This family includes bivalves with mytiloid or subquadrangular shells which superficially resemble the ark shells but are distinguished by the two lamellar cardinal teeth on the hinge plate. The shells have rather strong radiating, somewhat nodulose ribs, and the surface is covered by a hairy brown periostracum. The umbones are large and prominent, and directed anteriorly; the ligament is external. The pallial line is simple and a byssus is usually present.

Cardita aviculina Lamarck, 1819. Fig. 180 A, B. (Synonyms: *Cardita muricata* Sowerby, Edmondson, 1933; *C. hawaiensis* Dall, Bartsch, and Rehder, 1938; *C. cruda* Dall, Bartsch, and Rehder, 1938; *C. laysana* Dall, Bartsch, and Rehder, 1938.) Height, 10 mm; length, 6 mm; diameter, 5 mm. *Shell:* subquadrate, solid; equivalve;

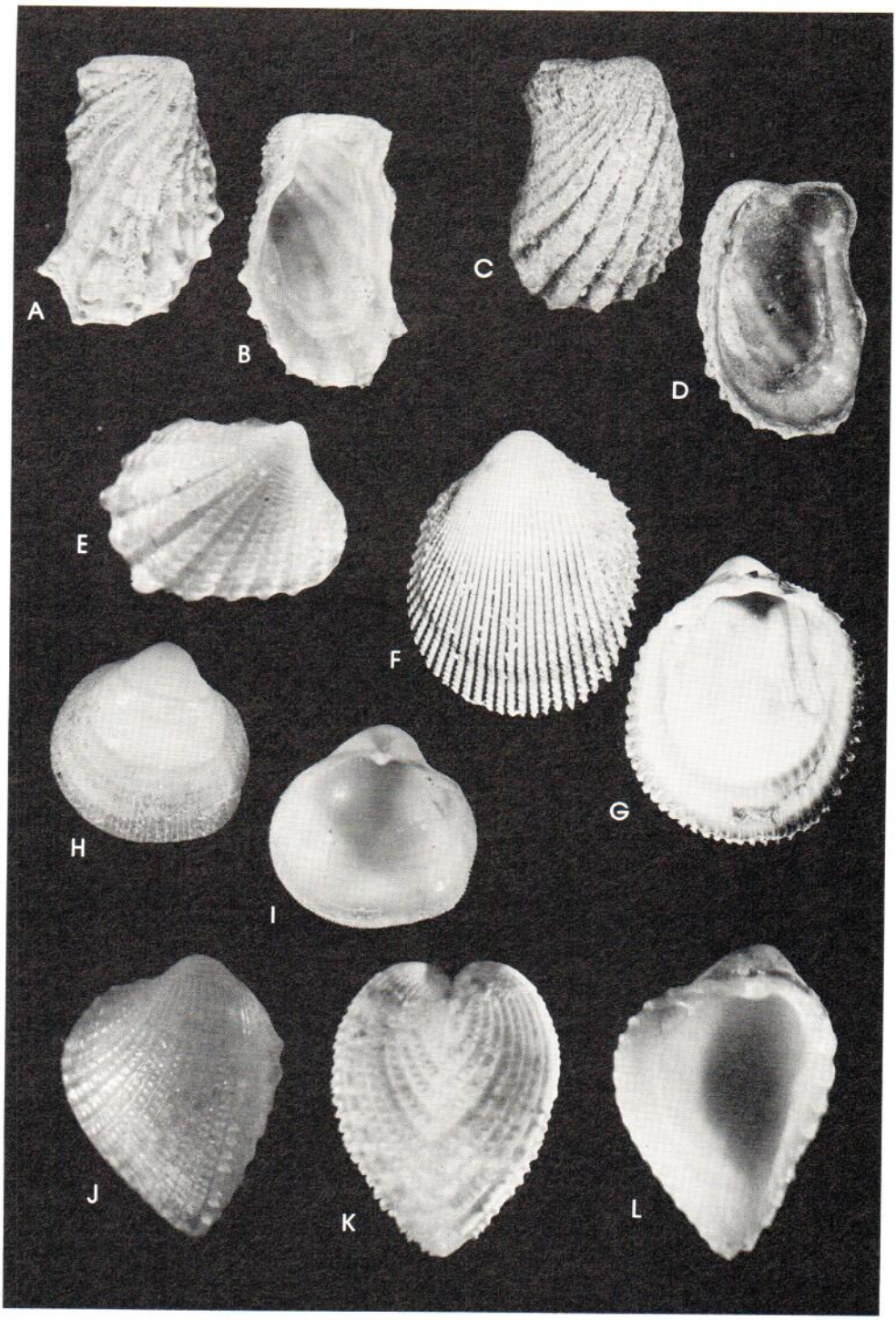


Figure 180.—A, B. *Cardita aviculina*, height 10 mm. C, D. *C. thaanumi*, height 11 mm. E. *Carditella hawaiensis*, height 3 mm. F, G. *Trachycardium orbita*, height 65 mm. H, I. *Nemocardium thaanumi*, height 7.5 mm. J, K, L. *Fragum mundum*, height 10 mm.

inequilateral, beaks almost terminal; with strong, boldly nodular or spiny radiating ribs; yellow or white. *Hinge:* shallow, semicircular, with two oblique ridges posteriorly and a single ridge anteriorly. *Sculpture:* strong radiating ribs equal in diameter to the interspaces crossed by low, rounded, concentric lamellae, the ribs spiny or nodular at the junctions; wing with five radiating threads, edge denticulated. *Color:* cream-yellow or white.

These bivalves occur in shallow water where they are found attached to the undersurfaces of rocks by the byssus; specimens have also been dredged to depths of 100 m.

C. aviculina occurs through the Indo-West Pacific.

Cardita thaanumi (Dall, Bartsch, and Rehder, 1938). Fig. 180 C, D. Height, 11 mm; length, 6 mm; diameter, 6 mm. *Shell:* elongate, with a winglike bulge at the dorso-anterior margin; equivalve; inequilateral; the beaks almost terminal; with coarse radiating ribs crossed by concentric lamellae; cream. *Hinge:* anterior lunule present; ligament narrow and curved; hinge with two irregular oblique folds in the left valve and corresponding teeth in the right valve. *Sculpture:* coarse radiating ribs which are strongest medially; six threads on the wing and 13 to 14 ribs on the remainder of the shell; concentric sculpture of closely spaced concentric lamellae imbricating the ribs. *Color:* cream-white.

These bivalves occur in shallow water attached by the byssus to the undersurface of rocks, and specimens have also been dredged to depths of 100 m.

C. thaanumi was described from the Hawaiian Islands.

Additional Record

Cardita excisa Philippi, 1847, a small white and brown shell (height, 1 mm; length, 2 mm), has not been recognized since the original description.

Family **Condylocardiidae**

The shells in this family are small, ovate or suborbicular, and the beaks may be topped with an exaggerated prodissoconchal cap edged by an upturned or raised rim. The surface is smooth or sculptured with strong, radial riblets and concentric lines. The ligament is weak, mostly internal. In the hinge plate the cardinal and lateral teeth are often merged.

Carditella hawaiensis Dall, Bartsch, and Rehder, 1938. Fig. 180 E. Height, 3.1 mm; length, 3.8 mm; diameter, 2.4 mm. *Shell:* subquadrate, equivalve; with strong radiating folds crossed by concentric lamellae; cream yellow. *Hinge:* a big median triangular fold in the right valve with a lateral oblique fold on each side; right valve with a corresponding median pit and two strong folds. *Sculpture:* about 11 strong, radiating folds, the interspaces of greater diameter; ribs and interspaces crossed by concentric lamellae which produce tilelike elements. *Color:* cream-yellow.

These bivalves occur at depths of 66 to 100 m.

C. hawaiensis was described from the Hawaiian Islands.

Superfamily CARDIACEA

Family **Cardiidae**

The cardiids, "heart shells" or "cockles," have rounded or ovate, equivalve shells with prominent beaks which are directed inward and almost touch one another. The surface of the shell is sculptured with radiating ribs and the ventral margin is serrate or crenulate. The ligament is external, consisting of a prominent dark brown, arched band behind the beaks. There are prominent, simple, hook-shaped cardinal teeth on the hinge. The adductor muscle scars are subequal, the pedal distinct and usually distant.

Cardiids are well known in temperate waters as inhabitants of sand or mud flats at or just below the surface where they move about with short leaps engendered by their long foot.

The three genera which are represented in Hawaiian waters are readily distinguished: the shells are small (about 10 mm in height) in *Fragum* and *Nemocardium*, the former distinguished by the sharp ridge which defines the posterior area of the shell, the latter by the quadrate shape; in *Trachycardium* the shell is large (up to about 70 mm in height), ovate and strongly ribbed.

Fragum (Fragum) mundum (Reeve, 1845). Fig. 180 J, K, L. (Synonyms: *Cardium arcuatulum* Sowerby, Pilsbry, 1921; *Fragum thurstoni* Dall, Bartsch, and Rehder, 1938.) Height, 10 mm; length, 7 mm; diameter (single valve), 8 mm. *Shell:* trapezoidal, solid; equivalve; umbonal angle high and sharp, posterior side flattened and the margin toothed; with sharp somewhat scaly radiating cords. *Hinge:* with two cardinals approximating each other in a V-shape and two erect laterals. *Sculpture:* prodissoconch smooth; remainder of valves with flat-topped ribs which are rectangular in cross section, the interspaces subequal and deep; interspaces with concentric threads and the ribs on the posterior surface with a periostracal layer of imbricated scales. *Color:* white or yellow.

These bivalves are common in shallow water, occurring singly nestling in the algal-sand mat of tide pools and shoreward on fringing reefs.

The Hawaiian shells are not distinguishable from Reeve's (1845) types of the widespread Indo-West Pacific species.

Nemocardium thaanumi (Pilsbry, 1921). Fig. 180 H, I. Height, 7.5 mm; length, 7 mm; diameter, 6 mm. *Shell:* hemispherical, thin, equivalve; anterior margin a little more strongly curved than posterior; with slender radiating threads crossed by concentric threads; white. *Hinge:* narrow; left valve with two erect cardinals and elongate laterals; right valve with the ventral cardinal larger than the dorsal. *Sculpture:* numerous (135 or more) slender radiating ribs separated by impressed interspaces crossed by regularly spaced concentric threads with elevated spines at the junctions. *Color:* white, the external sculpture showing through.

These cardiids occur at depths of from 16 m to 200 m, with one report of valves at depths of 500 m (Dall, Bartsch, and Rehder, 1938). They are not common,

occurring in fewer than one percent of the dredge hauls of both the *Pele* and the *Albatross*, but appear to be most frequent at depths of 25 to 50 m.

N. thaanumi was described from the Hawaiian Islands; shells similar to the Hawaiian shells have been dredged in the Marquesas (Rehder, pers. comm.)

Trachycardium orbita (Sowerby, 1833). Fig. 180 F, G. (Synonyms: *Cardium orbiter* Reeve, Bryan, 1915; *Trachycardium hawaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 65 mm; length, 53 mm; diameter, 40 mm. *Shell:* ovate, solid, equivalve, inflated; beaks full and prominent; with flatted spinous ribs; margins fluted and denticulated; flesh-colored maculated with brown. *Hinge:* broad and strong with a strong cardinal in each valve; left anterior and right posterior cardinals well developed, the left posterior and right anterior cardinals obsolete; laterals strongly developed and projecting. *Sculpture:* about 42 large, high, flattened ribs separated by narrow, deep interspaces; ribs imbricated with distantly spaced spinous scales. *Color:* exterior flesh, tinged with spots of chestnut brown, edge becoming purplish; interior with a purple border and irregular purple zones within.

This is a commonly occurring species in shallow waters shoreward of fringing reefs and to depths of less than 20 m; occasional valves have been dredged to depths of 60 m.

T. orbita is a wide-ranging species in the Indo-West Pacific.

Superfamily MACTRACEA

This superfamily encompasses several groups of shells which are in general solid and well-formed, and which have a distinctive hinge structure consisting of well-developed cardinal and lateral teeth and a triangular ligament pit or chondrophore. The shells are equivalve, inflated, lacking sculpture and usually of dull color. The adductor muscle scars are about equal in size and there is always a distinctive pallial sinus on the pallial line indicating the burrowing habit of these clams.

Family **Mactridae**

The shells of the Mactridae are characterized by a large, socket-like chondrophore or resilifer which encloses the internal portion of the ligament, the resilium. The chondrophore is just back of the A-shaped cardinal teeth; lateral teeth are also present on the dorsal margin of the hinge. The pallial sinus is deep and rounded.

Mactrid shells are trigonal to ovate in shape, usually of medium to large size, and porcelaneous. The outer layer of the periostracum is either shiny or matlike and is tinged with some shade of olive or buff. Typical mactrids have short siphons and a medium-sized foot. They are found all over the world, burrowing to a depth of a few centimeters in the sand or mud of beaches and harbors. A few are adapted to other modes of life.

Mactra thaanumi Dall, Bartsch, and Rehder, 1938. Fig. 181 A, B. Height, 12 mm; length, 16 mm; diameter, 8 mm. *Shell:* subtriangular, equivalve; equilateral;

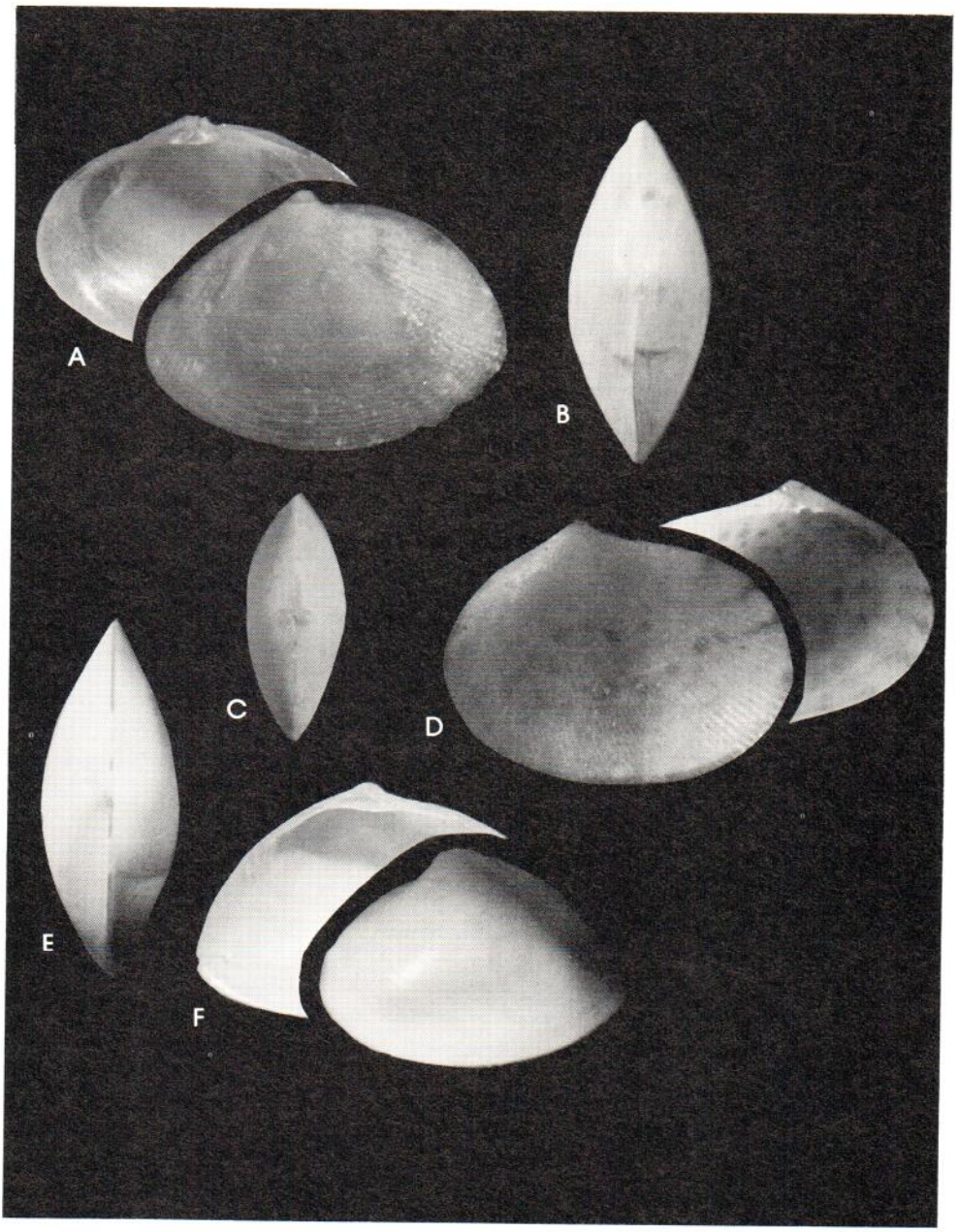


Figure 181.—A, B. *Mactra thaanumi*, length 16 mm. C, D. *Ervilia bisculpta*, length 4 mm. E, F. *E. sandwichensis*, length 3 mm.

surface with growth lines; white. *Hinge:* ligament external and posterior; hinge narrow, curved, left valve with conspicuous anterior and posterior teeth and posterior and anterior laterals. *Sculpture:* growth lines only. *Color:* white; periostracum pale yellow.

This species occurs at moderate depths and in deep water, at depths of 8 to 100 m.

M. thaanumi was described from the Hawaiian Islands.

Family **Mesodesmatidae**

These bivalves are solid, donaciform, and strongly inequilateral with the anterior side much longer than the posterior. The external surface is smooth, usually polished and covered in life with a thick, often glossy periostracum. The hinge is much like it is in the Mactridae, with the ligament largely internal, lodged in a deep pit or chondrophore bordered by the cardinal lateral teeth. Free, naked, retractable siphons distinguish this group from the mactrids.

Ervilia (Spondervilia) bisculpta Gould (1861). Fig. 181 C, D. (Synonym: *Ervilia ambla* Dall, Bartsch, and Rehder, 1938.) Height, 3 mm; length, 4 mm; diameter, 2 mm. *Shell:* elongate-ovate, equivalve, inflated; radial sculpture on posterior and anterior sides only; white, sometimes faintly spotted. *Margins:* beaks anterior to the midline; dorsal margin more convex than ventral edge, ventral edge denticulate, anterior and posterior margins strongly convex, somewhat attenuated. *Hinge:* internal ligament short, stout, in a rather broad, triangular pit; left valve with a narrow, low cardinal and a strong, rather long anterior lateral and short, knoblike posterior lateral; right valve with a strong, prominent anterior cardinal and a short, obscure posterior lateral. *Sculpture:* conspicuous radial riblets at the anterior and posterior ends which are rendered nodulose by the concentric lirae, medial section of valves with concentric growth lines. *Color:* white, sometimes with one or two pink spots.

Valves are occasionally found subtidally from depths of 10 to 100 m.

E. bisculpta was described from Kagoshima, Japan, and is widely distributed in the Pacific.

Ervilia sandwichensis (Smith, 1885). Fig. 181 E, F. (Synonym: *Rochefortina semele* Dall, 1924.) Height, 2 mm; length, 3 mm; diameter, 1.5 mm. *Shell:* ovate, moderately inflated; inequilateral; surface with crowded radial riblets crossed by concentric lirae; white, yellow, pink spotted with brown. *Margins:* beaks anterior to the midline; anterior and ventral margins convex, posterior margin blunt. *Hinge:* internal ligament stout, short, in a triangular chondrophore under the beak; left valve with a projecting anterior cardinal, a small posterior cardinal, and a deep, elongate triangular pit separating it from a strong, elongate anterior lateral, posterior lateral low; right valve with a strong anterior cardinal in front of the chondrophore and a smaller one behind it; anterior and posterior laterals long. *Interior:* muscle scars subequal, the anterior elongate-ovate, the posterior suborbicular; pallial line with a moderately deep sinus. *Sculpture:* flattened, crowded radial riblets crossed by strong, crowded concentric lirae which render the ribs subnodose. *Color:* white, yellow, or occasionally irregularly spotted with brown.

These bivalves are very common in shallow water and to depths of 60 meters.

This species was described from the Hawaiian Islands and also occurs in New South Wales, Australia (= *Ervilia simplex* Laseron, 1953) and in Japan (Sakurai and Habe, 1973).

Superfamily TELLINACEA

Family **Tellinidae**

The tellens are active, burrowing bivalves with a large foot and long, separate siphons. They usually assume a horizontal position in a sandy substrate, and in many species the posterior margins of the shell are flexed and directed toward the surface of the substrate; it is from this gape that the incurrent siphons emerge, drawing in from the surface of the substratum organic detritus on which they subsist.

Tellen shells are usually thin, somewhat flattened, and equivalve, although one valve is sometimes larger than the other. The beaks are normally in the posterior half of the shell, and the ligament is external. There are two cardinal teeth in each valve and the laterals are weak. These shells are often remarkable for their bright colors. Some have a peculiar external superficial sculpture which has been suggested as offering a resistance to posteriorly directed movements, and thus being of selective advantage in maintaining the position of the animals in the substrate when the siphons are withdrawn (Boss, 1965a).

Macoma (Scissulina) dispar (Conrad, 1837). Fig. 182 I, J. Height, 23 mm; length, 34 mm. *Shell:* elongate to subrectangular, slightly inflated; left valve of greater convexity than the right and with a definitive posterior flexure to the right; white. *Margins:* evenly curved, the ventral margin slightly insinuated at the posterior angle and with a weak angulation from umbo to posterior margin in right valve. *Hinge:* ligament short, external and protuberant; hinge with a strong groove and a low, divergent cardinal tooth complex in each valve, no laterals. *Sculpture:* concentric lines of growth with radiating striations in the left valve and scissulate or acentric sculpture in the right. *Color:* white, sometimes suffused with yellow toward the umbones.

These bivalves are locally abundant in shallow water and to depths of 20 m in silty sand in bays where there is freshwater outflow such as at Hanamaulu, Kauai, and Hilo Bay, Hawaii. They were formerly abundant on Oahu in Honolulu Harbor, Pearl Harbor, and Kaneohe Bay.

M. dispar was described from the Hawaiian Islands but is widely distributed in the Indo-West Pacific from the east coast of Africa to Micronesia and Polynesia (Boss, 1969).

Macoma (Scissulina) obliquilineata (Conrad, 1837). Fig. 182 G, H. Height, 8 mm; length, 15 mm. *Shell:* ovate-elongate; with fine concentric threads; white. *Margins:* evenly curved. *Hinge:* ligament short, external; cardinals of right valve unequal, anterior shorter than posterior, and posterior cardinal grooved; posterior cardinal of left valve elongate, anterior knoblike. *Interior:* pallial sinus confluent with pallial line. *Sculpture:* obsolete, closely approximated concentric threads, incremental lines and radial striae; middle part of shell also with oblique striations. *Color:* white or rayed with rose.

M. obliquilineata occurs at depths of from 12 to 100 m in clean sand, often with various species of *Terebra*.

This species was described from the Hawaiian Islands.

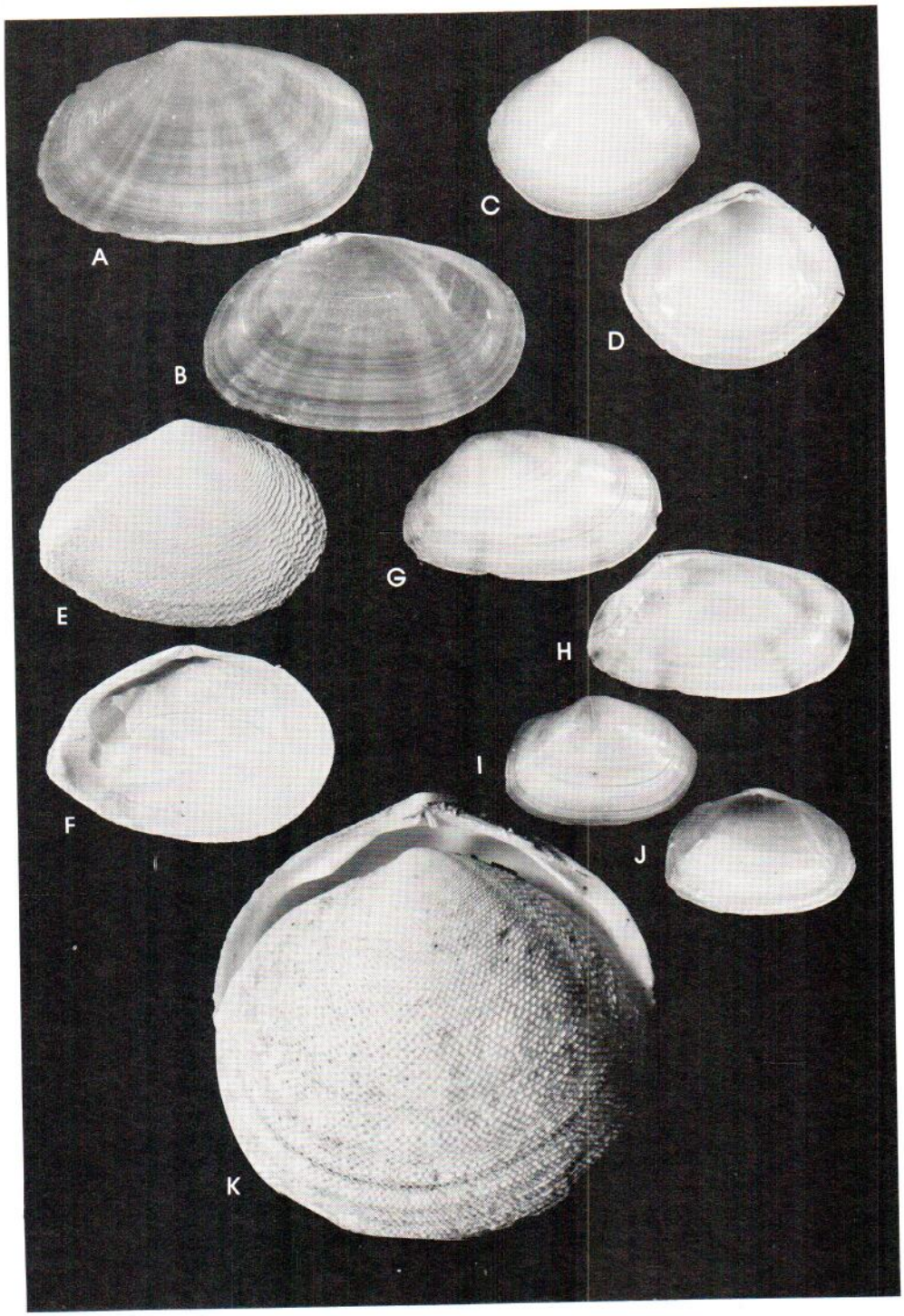


Figure 182.—**Tellinidae.** A, B. *Tellina hawaiensis*, length 20 mm. C, D. *T. robusta*, length 12 mm. E, F. *T. palatam*, length 66 mm. G, H. *Macoma obliquilineata*, length 15 mm. I, J. *M. dispar*, length 34 mm. K. *Tellina elizabethae*, length 56 mm.

Tellina (Angulus) hawaiensis Dall, Bartsch, and Rehder, 1938. Fig. 182 A, B. Height, 12 mm; length, 20 mm. *Shell:* oval, thin, fragile; glassy with pale rose rays. *Margins:* anterior and posterior evenly curved; ventral edge with a slight bow. *Hinge:* ligament short; right valve with two narrow, divergent cardinals, one anterior lateral; left valve with a stout, triangular anterior cardinal. *Sculpture:* fine incremental lines and microscopic radiating striae. *Color:* translucent, glassy white with pale rosy rays.

These bivalves are uncommon, dredged from depths of about 16 m off the leeward coasts of Oahu and Maui.

T. hawaiensis was described from the Hawaiian Islands.

Tellina (Arcopagia) elizabethae Pilsbry, 1918. Fig. 182 K. Height, 48 mm; length, 56 mm; diameter, 23 mm. *Shell:* subcircular, solid; with lunate scales; white. *Margins:* anterior and posterior curving from the beaks almost in a semicircle to the middle of the ventral margin. *Hinge:* ligament moderately long and rather prominent, two cardinals in each valve, the right valve with the anterior cardinal small and vertical, posterior large and obliquely grooved; anterior cardinal of left valve large, vertical and grooved, posterior small, sublamellar and obliquely situated; laterals small, sublamellar in right valve, obscure in left. *Sculpture:* numerous lunate scales, the open curve ventral, arranged in a regular pattern rendering the surface filelike. *Color:* white.

These bivalves are common in the silty sand inshore on fringing reefs on the leeward coasts of the windward islands.

T. elizabethae was described from the Hawaiian Islands and from Flint Island. Pilsbry (1918) distinguished these tellinids from the widely distributed *T. scobinata* Linnaeus, 1758, by the more produced beaks, straight slopes in front and behind the beaks, less deeply curved margin, and the much smaller scales.

Tellina (Arcopagia) robusta (Hanley, 1844). Fig. 182 C, D. (Synonym: *Angulus nucella* Dall, Bartsch, and Rehder, 1938.) Height, 9 mm; length, 12 mm. *Shell:* suborbicular, inflated; barely inequilateral; with concentric distantly spaced, fragile lamellae ventrally; white. *Margins:* anterior and posterior edges evenly curved, posterior margin slightly angled where it joins the ventral margin; ventral edge curved. *Hinge:* ligament on a short escutcheon; right valve with anterior cardinal fused to lunular shelf, posterior cardinal bifid, laterals short and lamellar; left valve with a single, bifid cardinal, fused with dorsal margins. *Interior:* adductor muscle scars of equal size. *Sculpture:* regularly, distantly spaced fragile lamellae. *Color:* white, interior sometimes with yellow.

These bivalves are found at depths of 8 to 16 m in clean sand with several species of *Terebra*.

T. robusta occurs throughout the Indo-West Pacific from the east coast of Africa to Micronesia and Polynesia.

Tellina (Cadella) oahuana Dall, Bartsch, and Rehder, 1938. Fig. 183 C, D. (Synonym: *Cadella mauia* Dall, Bartsch, and Rehder, 1938.) Height, 4 mm; length, 6 mm. *Shell:* ovate-triangular, solid; inequilateral, umbones behind the midline; with concentric threads; white. *Margins:* dorsal line gently curving; anterior margin nar-

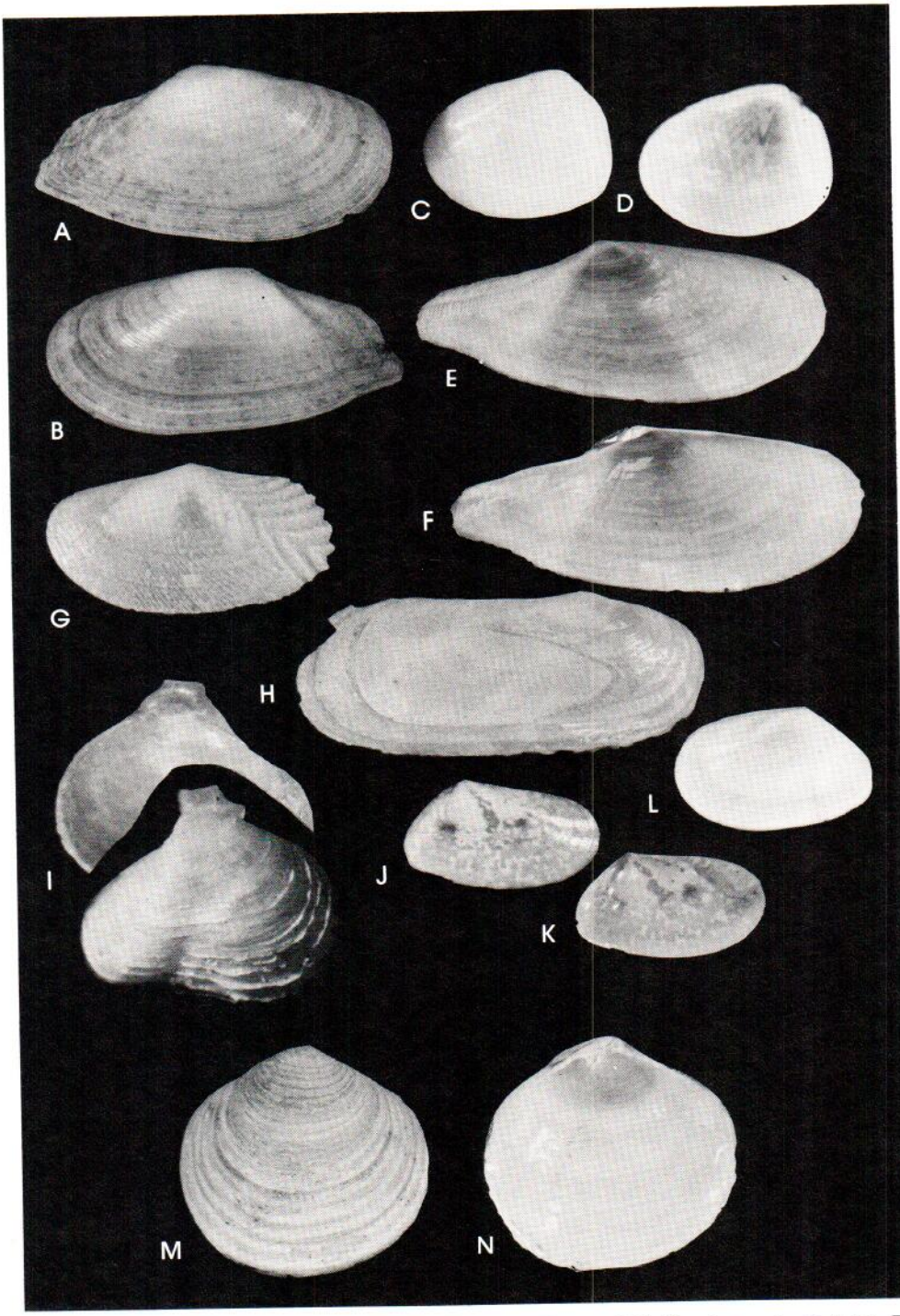


Figure 183.—**Tellinidae.** A, B. *Tellina crucigera*, length 33 mm. C, D. *T. oahuana*, length 6 mm. E, F. *T. perna*, length 42 mm. G. *Grammatomya kanaka*, length 15 mm. H. *Solecurtus baldwini*, length 17 mm. I. *Lonoa hawaiensis*, length 6 mm. J, K, L. *Semelangulus crebrimaculatus*. (J-K) length 9.7 mm (L) length 6 mm. M, N. *Semele australis*, length 24 mm.

rowly and smoothly rounded; posterior margin sloped, forming a bluntly rounded truncation; ventral margin rounded. *Hinge:* right posterior and left anterior cardinal teeth stout, triangular; right anterior cardinal lamellar, left posterior cardinal thin; lateral teeth developed in left valve. *Sculpture:* low, rounded concentric threads becoming lamellar posteriorly. *Color:* white, sometimes with spots and blotches of flake white.

This species is known only from beachworn valves, a valve dredged by the *Albatross* at a depth of 26 m, and a specimen dredged by the *Pele* "off Waikiki."

T. oahuana was described from the Hawaiian Islands, but it may represent *T. semen* Hanley, 1844, which ranges through the Indo-West Pacific from the east coast of Africa to the Philippines, Marshall Islands, and Fiji.

Tellina (Pharaonella) perna (Spengler, 1798). Fig. 183 E, F. (Synonym: *Tellina venusta* Deshayes, 1854.) Height, 16 mm; length, 42 mm. *Shell:* subelliptical, beaked posteriorly; thin and translucent with microscopic concentric striae; polished white. *Margins:* dorsal margin nearly straight; anterior margin narrowly rounded; with a low, flattened ridge from umbo to posterior ventral surface; valves sharply flexed posteriorly. *Hinge:* ligament external in a depressed escutcheon; two cardinal teeth in each valve, the right posterior and left anterior larger and grooved; anterior and posterior laterals of right valve lamellar, not developed in left valve. *Interior:* muscle scars moderately well impressed. *Sculpture:* microscopic concentric striae only. *Color:* white, usually suffused with yellow.

These bivalves are only occasionally dredged at depths of 15 m off the leeward coasts of the windward islands but are very common in beach drift at Midway.

T. perna is widely distributed in the Indo-West Pacific, from the east coast of Africa to the Cocos-Keeling Islands in the Indian Ocean, and in the Pacific to southern Japan and Polynesia (Boss, 1969). In Hawaii, valves are usually larger than those of typical *T. perna* from the central portion of their range, and often possess reddish radiations on the beak (Boss, 1969).

Tellina (Quidnipagus) palatam Iredale, 1929b. Fig. 182 E, F. (Synonym: *Tellina rugosa* Born, Lynge, 1909.) Height, 48 mm; length, 66 mm. *Shell:* ovate, compressed; with regularly spaced concentric cords; white. *Margins:* beaks projecting; ventral posterior margin of right valve upturned and overriding left; posterior edge narrowed, beaked, and sinuous. *Hinge:* ligament external in a depressed escutcheon; left valve with a stout, triangular grooved anterior cardinal and narrow, obliquely diverging posterior cardinal, laterals fused with dorsal margin; right valve with two subequal divergent cardinals, the posterior larger and grooved, laterals strong and separate from the dorsal margin. *Sculpture:* fine radiating threads and regularly spaced concentric cords which become lamellar. *Color:* white.

These bivalves are found in silty sand inshore on fringing reefs and at depths of from 2 to 3 m. They can be located by noting the small openings the siphons make at the surface of the sand in which they lie buried.

T. palatam is distributed throughout the Indo-West Pacific from the coast of east Africa to the Philippines, southern Japan, Fiji and the Society Islands.

Tellina crucigera Lamarck, 1818. Fig. 183 A, B. (Synonyms: *Tellina exculta hawaiensis* Pilsbry, 1918; *T. crassiplicata* Dall, Bartsch, and Rehder, 1938.) Height, 16 mm; length, 33 mm. *Shell:* elongate-ovate; equivalve; inequilateral; beaked posteriorly; with concentric threads; yellow, rayed with red-brown. *Margins:* anterior and ventral margins evenly curved; posterior end upturned; a narrow, wedge-shaped ridge extending from umbo to posterior ventral margin. *Hinge:* ligament a bullet-shaped brown wedge extending about one-quarter the way from beak to posterior margin; two cardinals and two lateral teeth in each valve. *Sculpture:* well-rounded, evenly spaced concentric cords forming lamellae on the posterior area, with fine, microscopic threads between the cords and lamellae. *Color:* yellow or white, variously rayed with red-brown; interior yellow.

These tellinids are uncommon in shallow water and more characteristic of depths of 8 to 100 meters.

This species is widely distributed in the Indo-West Pacific, occurring from the east coast of Africa through the Indian Ocean to southern Japan and Polynesia.

Family **Psammobiidae**

(Garidae)

Although these bivalves are sometimes called sunset clams elsewhere because of their bright colors, the Hawaiian representatives of the family are white or cream-colored. The psammobids are burrowers and the Hawaiian species are found in rather deep water.

The shells are round, quadrangular, or elongate-ovate in outline, generally compressed and thin, and there is a horny periostracum which often peels off dry shells. A prominent external ligament lies posterior to the beaks and rises above the hinge. The hinge teeth are small, lying near the center of the dorsal margin; there are two small cardinals in each valve and either or both may be bifid. The pallial sinus is large.

Grammatomya kanaka (Pilsbry, 1921). Fig. 183 G. Height, 8 mm; length, 15 mm. *Shell:* ovate, thin; with concentric threads and radial ribs posteriorly; white. *Margins:* dorsal and ventral edges curving; anterior and posterior margins rounded; with a strong ventral gape. *Hinge:* right valve with two, strong, subequal, divergent hooklike cardinals; left valve with a single cardinal. *Sculpture:* concentric threads dorsally which become almost lamellar ventrally and the posterior surface strongly sculptured by rounded ribs which bifurcate toward the bottom. *Color:* white with a roseate ligament.

These bivalves have been dredged from depths of 1 to 100 m.

G. kanaka was described from the Hawaiian Islands.

Solecurtus baldwini Dall, Bartsch, and Rehder, 1938. Fig. 183 H. Height, 7 mm; length, 17 mm. *Shell:* oval with parallel dorsal and ventral margins; thin; white. *Margins:* anterior and posterior edges rounded; dorsal and ventral margins parallel. *Hinge:* left valve with anterior cardinal thin, strong, hooklike, posterior cardinal slender, obscure, divergent; right valve with a strong, pointed, hooklike cardinal and divergent, erect, sublamellar posterior cardinal. *Sculpture:* dorsally with growth lines,

central and posterior portion with incised, divaricating lines forming triangles the apices of which are in a line which extends from the umbo to the posterior ventral margin. *Color:* white.

These bivalves live in deep water at depths of 120 to 500 m.

S. baldwini was described from the Hawaiian Islands.

Additional Record

Dysmea vitrea Dall, Bartsch, and Rehder, 1938 was described from a single specimen dredged by the *Albatross* at depths of 86 to 122 m. It has an oval, thin, fragile shell, sculptured only with growth lines; the dimensions are: height, 18 mm; length, 33 mm.

Family **Semelidae**

The semelids resemble the tellinids but are distinguished by their ligament which is largely lodged in a capsule on the hinge plate back of the two small cardinal teeth, and by their deep, widely rounded pallial sinus. The family is widely distributed in tropical seas.

Lonoa hawaiensis Dall, Bartsch, and Rehder, 1938. Fig. 183 I. Height, 5 mm; length, 6 mm. *Shell:* subtriangular, inflated, thin; equivalve; inequilateral, the beak posterior to the midline; with fine concentric growth lines; white. *Margins:* beaks strongly projecting; anterior edge produced and rounded; posterior margin truncate; ventral edge constricted. *Hinge:* ligament short, external; left valve with a strong triangular cardinal tooth and a deep pit; right valve with two diverging cardinal teeth. *Sculpture:* fine, concentric growth lines which are more pronounced toward the ventral margin. *Color:* white.

These bivalves are known only from occasional valves found in drift; the ventral marginal constriction suggests a nestling habit.

L. hawaiensis was described from the Hawaiian Islands.

Semelangulus crebrimaculatus Sowerby, 1867. Fig. 183 J, K. (Synonyms: *Semelangulus dichrous* Dall, Bartsch, and Rehder, 1938; *S. diodorus* Dall, Bartsch, and Rehder, 1938; *S. nebulosus* Dall, Bartsch, and Rehder, 1938; *S. oahuensis* Dall, Bartsch, and Rehder, 1938.) Height, 5.6 mm; length, 9.7 mm. *Shell:* donaciform; equivalve and equilateral; smooth; white tinted with yellow and with a red spot. *Margins:* beaks projecting slightly above dorsal margin; dorsal edge almost straight; ventral margin slightly curved; anterior margin drawn out and rounded; posterior edge truncate; with an obscure ridge from umbo to ventral-posterior margin. *Hinge:* external ligament short, in a depressed escutcheon; internal ligament in a depressed groove posterior to cardinal; right valve with a stout, triangular, grooved posterior cardinal, short sublamellar anterior cardinal, strong laterals; left valve with a stout, rather narrow, slightly anterior grooved cardinal, thin, rather short posterior cardinal, obscure laterals. *Color:* white tinted with yellow and with a commalike red spot posterior to the umbo.

These bivalves occur at depths of from 1 to 16 m.

S. crebrimaculatus was described from Lord Hood Island. The four species described by Dall, Bartsch, and Rehder (1938) appear to be only variants of a single species.

Semele australis (Sowerby, 1832). Fig. 183 M, N. (Synonym: *Semele tita* Dall, Bartsch, and Rehder, 1938.) Height, 24 mm; length, 24 mm. *Shell:* subcircular, solid, equivalve and equilateral; with concentric lamellae; white. *Margins:* beaks projecting slightly above dorsal line; dorsal and ventral margins curved; anterior edge slightly more rounded than posterior. *Hinge:* ligament external, short, narrow; with two divergent cardinals in each valve and an anterior and posterior lateral. *Sculpture:* concentric threads becoming strong lamellar cords ventrally, with finer concentric threads between, cords sometimes obsoletely nodular. *Color:* white.

These bivalves occur in shallow water and to depths of a few meters.

S. australis was described from Lord Hood Island and also occurs in the Marshall Islands and the Tuamotus. Although Dall, Bartsch, and Rehder (1938) distinguished *S. australis* by its heavier and more pronounced radial sculpture, the Hawaiian shells are indistinguishable from Sowerby's types.

Superfamily ARCTICACEA

Family **Trapeziidae**

Members of this family live in sand or in crevices underneath coral blocks on reefs and in shallow water. The shells are subtrapezoidal in shape with rather prominent umbones; they are covered with a thin, brown periostracum.

Trapezium oblongum (Linnaeus, 1758). Fig. 184 E, F. (Synonyms: *Trapezium californicum* Conrad, 1837; *Cypricardia duperryi* Deshayes, Carpenter, 1864.) Height, 21 mm; length, 39 mm; diameter, 28 mm. *Shell:* trapezoidal, inflated, solid; equivalve; inequilateral, the beaks anterior; with radiating threads rendered nodular by concentric threads; white. *Margins:* beaks moderately elevated and incurved; posterior margin strongly curved; ventral edge slightly constricted; with two radiating keels from the umbo to the ventral edge. *Hinge:* ligament external; left valve with three cardinal teeth, the two anterior joined basally and forming a triangle, the dorsal cardinal parallel to the hinge line; right valve with two laterals between which is a pit which engages the tooth of the opposite valve. *Sculpture:* radiating riblets nodular where they are crossed by concentric threads. *Color:* white; interior with a few purple-red spots.

This is a common shallow-water bivalve, occurring along the shorelines of all the Hawaiian Islands. It has been recorded from Pleistocene fossil deposits on Oahu (Ostergaard, 1928, as *Trapezium duperryi).*

T. oblongum is distributed in the Indo-West Pacific from Madagascar to Hawaii (Solem, 1954).

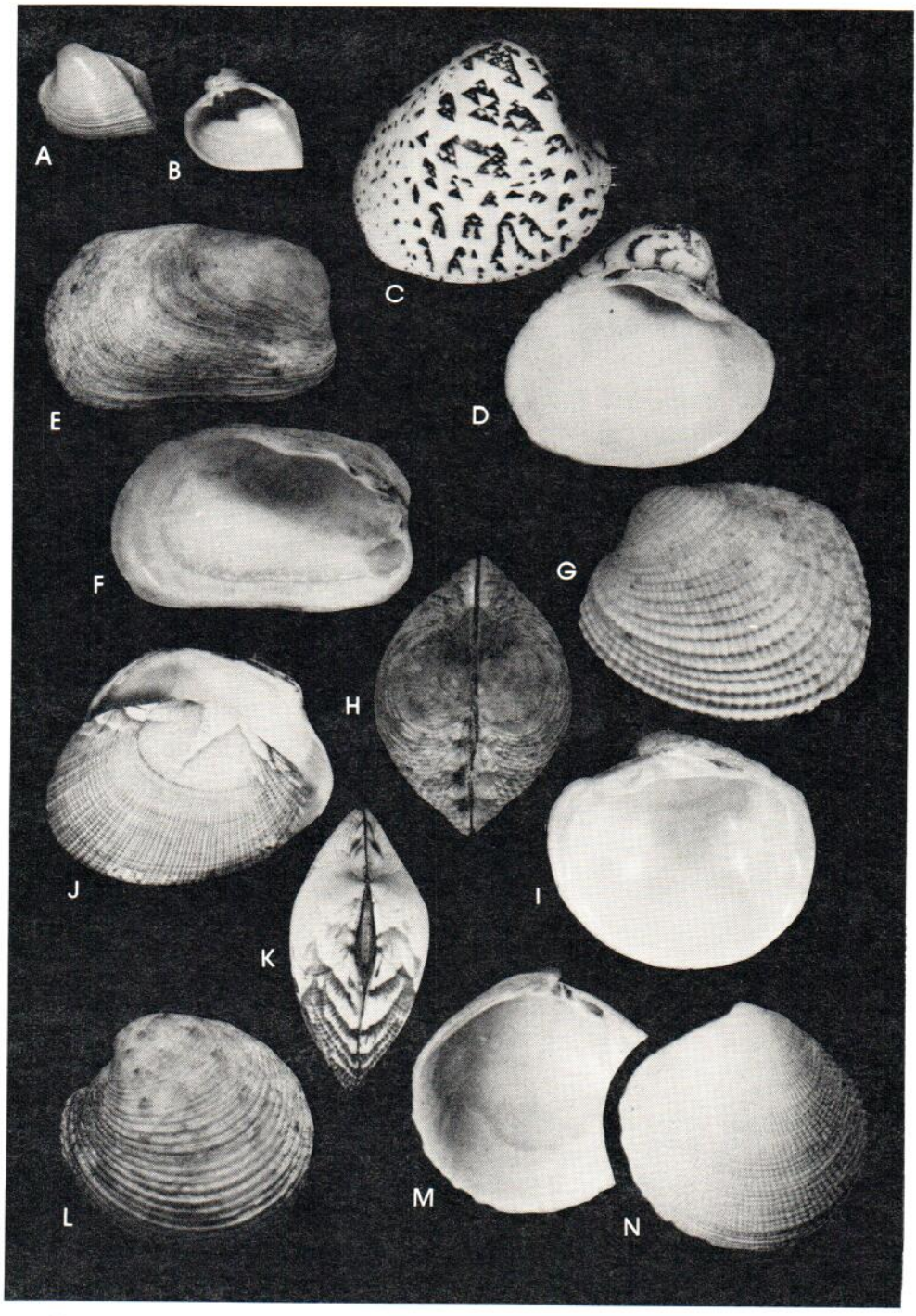


Figure 184.—**Glossidae.** A, B. *Meiocardia hawaiana*, length 15 mm. **Trapeziidae.** E, F. *Trapezium oblongum*, length 39 mm. **Veneridae.** C, D. *Lioconcha hieroglyphica*, length 33 mm. G, H, I. *Periglypta reticulata*, length 71 mm. J, K. *Tapes japonica*, length 40 mm. L. *Venis toreuma*, length 31 mm. M, N. *Gouldia cookei*, length 8 mm.

Superfamily GLOSSACEA

Family **Glossidae**

(= **Isocardiidae**)

The heart cockles have conspicuously inrolled umbones and polished, glossy shells. The valves are equivalve but inequilateral with the beaks in the anterior half. The sculpture is concentric. There is an external ligament and the cardinal and lateral teeth on the hinge plate lie more or less parallel to the dorsal margin.

These bivalves live in sand or silt at moderate depths and in deep water.

Meiocardia hawaiana Dall, Bartsch, and Rehder, 1938. Fig. 184 A, B. Height, 14 mm; length, 15 mm; diameter of single valve, 7 mm. *Shell:* subquadrate and heart-shaped, with strong incurved umbones and sharp angular keel; thin; sculpture of concentric cords; white. *Margins:* dorsal, margins anterior, and ventral gently curved; posterior edge slightly concave; with an angular keel radiating from the posterior end of the umbo to the ventral edge. *Hinge:* ligament narrow and arched; anterior cardinals short and diagonal; posterior cardinals longer and curved; posterior laterals long and straight. *Sculpture:* regularly spaced concentric cords, the interspaces of greater diameter; concave posterior portion with concentric threads. *Color:* polished, white.

These bivalves occur at depths of from 26 to 300 m.

This species was described from the Hawaiian Islands. It differs from *M. tetragona* (Adams and Reeve, 1848), which is widely distributed in the Indo-West Pacific, in having well-developed concentric cords rather than wrinkles, and inrolled rather than flatly curled umbones; from *M. cumingii* (A. Adams, 1864a) in lacking rose spotting on a cream background and keeled concentric cords; and from *M. vulgaris* (Reeve, 1845), which has an extremely curved apex.

Superfamily VENERACEA

Family **Veneridae**

This family includes a large number of rather spectacular shells with striking sculpture and a variety of color patterns. It is well known in both tropical and temperate waters where several species are sought after as items of food. The venerids are burrowers, but they burrow only a short distance beneath the surface of the substrate. It has been suggested that the bold sculpture on the shell may be an adaptation which keeps the shell immobile in a shifting substrate.

The shells are ovoid or suborbicular, usually thick and heavy, and the sculpture is radial or concentric. They are equivalve, usually inequilateral, and the beaks are normally near or in front of the midline and directed forward. The ligament is external and often deeply inset. There are two or three cardinal teeth which are often bifid and

laterals may also be present. The adductor muscle scars are about equal in size and the pallial sinus is well developed.

Gouldia cookei (Dall, Bartsch, and Rehder, 1938). Fig. 184 M, N. Height, 7 mm; length, 7 mm. *Shell:* suborbicular, compressed, solid; inequilateral, the beaks anterior to the midline; with fine radiating riblets beaded by equally fine spiral threads; white. *Margins:* beaks prominent; anterior, posterior, and ventral margins evenly convex. *Hinge:* ligament in a shallow nymph; each valve with three moderately diverging cardinals, the central tooth the shortest, the others sublamellar; left anterior lateral fits into a corresponding groove in the right valve. *Sculpture:* fine, diverging radiating riblets regularly beaded by concentric threads of equal diameter. *Color:* white.

These bivalves are known only from occasional shells found in drift and nothing is known of their habits.

G. cookei was described from the Hawaiian Islands.

Lioconcha hieroglyphica (Conrad, 1837). Fig 184 C, D. Height, 29 mm; length, 33 mm. *Shell:* subtriangular, solid; surface nearly smooth; yellow-white with dark brown hieroglyphics. *Margins:* beaks inflated, elevated; anterior end acutely rounded, posterior end truncate; ventral margin moderately rounded. *Hinge:* ligament posterior to umbones; anterior cardinals weak, central cardinals strong, posterior cardinal more or less joined to ligament shelf; left anterior lateral strong, fitting into a depression in the right valve. *Sculpture:* fine, incremental growth lines only. *Color:* yellow-white with dark brown hieroglyphics; with a heavy, slimy feltlike, white periostracum.

These bivalves occur in sandy substrates at depths of 1 to 100 m.

L. hieroglyphica was described from the Hawaiian Islands, but shells with similar color patterns occur in the Mariana and Marshall Islands.

Periglypta reticulata (Linnaeus, 1758). Fig. 184 G, H, I. (Synonym: *Periglypta edmondsoni* Dall, Bartsch, and Rehder, 1938.) Height, 60 mm; length, 71 mm. *Shell:* suborbicular, inflated, solid; with strong, concentric lamellae between which are fine axial threads; cream. *Margins:* beaks heavy and anteriorly depressed; dorsal and ventral margins curved. *Hinge:* broad, with three stout cardinals in each valve, the central cardinal deeply cleft. *Sculpture:* concentric lamellae the edges of which are oriented toward the umbo, with fine concentric threads and radiating ribs between the lamellae, the ribs rendering the lamellae nodulose at the junctions. *Color:* cream, sometimes flecked with brown.

This is a common species found in shallow water along all the shorelines of the Hawaiian Islands.

There seems no reason to distinguish the Hawaiian shells from the widespread, variable Indo-West Pacific species, as Dall, Bartsch, and Rehder (1938) have done.

Tapes japonica Deshayes, 1853. Fig. 184 J, K. (Synonym: *Tapes philippinarum okupi* Bryan, 1919.) Height, 32 mm; length, 39 mm; diameter, 21 mm. *Shell:* suboval, solid; with fine concentric threads and radiating riblets; gray, streaked and blotched

with brown. *Margins:* dorsal margin produced as a median rounded point; posterior margin truncate; ventral margin curved. *Hinge:* ligament elevated, between posterior margin and umbo; hinge with three short, prominent, diverging cardinals. *Sculpture:* numerous fine radiating riblets crossed by fine concentric threads which render the ribs slightly granular. *Color:* gray variously marked with patches of brown.

This bivalve was introduced on Oahu probably at the beginning of the century (Thaanum, 1921) and apparently spread rapidly in shallow bays such as at Kalihi, Maunalua, and Pearl Harbor. Abundance declined after the initial spread and the only area where it is exploited is in Kaneohe Bay, Oahu, where it was planted in 1920 (Edmondson and Wilson, 1940). Because of overfishing, however, these clam beds have been closed since 1969.

In Kaneohe Bay, Oahu, the clams occur in aggregations of as many as 30 per m^2 on the periphery of shallow water reef platforms in the southeastern section. The crabs *Thalamita* and *Calappa* and the gastropod *Natica gualteriana* are among their predators (Higgins, 1969; Yap, 1974). The larvae settle between February and June, with peak settling in April and May (Yap, 1974).

T. japonica is a well known bivalve throughout the Indo-West Pacific and was introduced to the west coast of the United States, probably with oyster spat, in 1943 (Hanna, 1966).

Venus toreuma Gould, 1850. Fig. 184 L. (Synonym: *Venus hawaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 31 mm; length, 34 mm. *Shell:* subcircular, inflated; with heavy concentric ridges between which are fine threads; white. *Margins:* beaks strong and arched; anterior margin convex, posterior margin less rounded; ventral edge curved. *Hinge:* ligament short, sunken; hinge with three strong cardinals in each valve, the central broader than the others and bifid; anterior cardinals curved and triangular and with a small tubercle, posterior cardinals narrow, curved. *Sculpture:* heavy concentric ridges with spaces of lesser diameter marked by concentric threads and feeble radiating threads; lateral and ventral margin internally finely denticulate. *Color:* white.

These clams occur at depths of 10 to 500 m.

V. toreuma was described from the Strait of Balabac, Philippine Islands; it also occurs in the Indian Ocean at Réunion (see *V. sculpta* Deshayes, 1863).

Superfamily HIATELLACEA

Family **Gastrochaenidae**

These bivalves are, like the Hiatellidae, borers. They burrow in soft rock and coral where they form flask-shaped excavations lined with calcareous material. The burrows communicate with the surface by a narrow neck or tube. The shells are thin, small, narrowly elongate, and inequilateral, and the ventral margin gapes broadly anteriorly. There are two adductor muscle scars and a deep pallial sinus.

Gastrochaena (Rocellaria) cuneiformis Spengler, 1783. Fig. 185 A. (Synonym: *Rocellaria lamellosa* Edmondson, 1924; *R. hawaiensis* Dall, Bartsch, and Rehder,

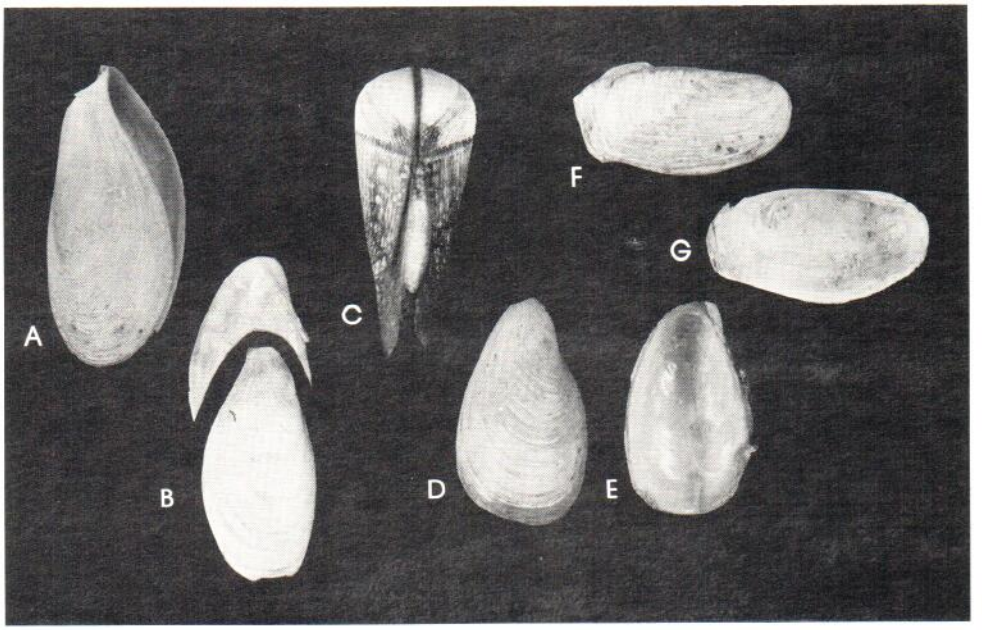


Figure 185.—A. *Gastrochaena cuneiformis*, length 35 mm. B. *G. oahuana*, length 12 mm. C. *Martesia striata*, length 32 mm. D, E. *Gastrochaena kanaka*, length 10 mm. F, G. *Hiatella arctica*, length 10 mm.

1938.) Height, 17 mm; length, 35 mm; diameter, 16 mm. *Shell:* ovate, anterior margin forming a beak; with concentric lamellae; yellow-white. *Margins:* dorsal margin with slightly raised beak; anterior edge beaked; posterior and ventral margins curved. *Hinge:* straight, thickened, toothless. *Sculpture:* numerous slender, concentric lamellae. *Color:* yellow-white. *Animal:* white with black siphons.

These bivalves bore into coral such as *Porites* in which they form an egg-shaped cavity.

G. cuneiformis is distributed throughout the Indo-West Pacific.

Gastrochaena (Rocellaria) kanaka Dall, Bartsch, and Rehder, 1938. Fig. 185 D, E. Height, 6 mm; length, 10 mm; diameter, 4 mm. *Shell:* oval, thin, with concentric threads; dark brown. *Margins:* dorsal margin almost straight with moderately projecting beaks; posterior dorsal and posterior ventral margins curved; ventral margin gaping. *Hinge:* straight; without teeth. *Sculpture:* closely spaced concentric threads which are more prominent toward the ventral edge. *Color:* dark brown.

Specimens of this species are found in burrows of *Porites* near those of *G. cuneiformis*.

This species was described from the Hawaiian Islands. The smaller size and dark brown shell distinguish this species from *G. cuneiformis*.

Gastrochaena (Rocellaria) oahuana Dall, Bartsch, and Rehder, 1938. Fig. 185 B. Height, 7 mm; length, 13 mm; diameter, 6 mm. *Shell:* oval; with concentric threads; white. *Margins:* beaks at the anterior end; dorsal line straight; posterior margin curved;

ventral margin with a broad, open sinus. *Hinge:* ligament external; hinge line straight, toothless. *Color:* milk white.

These bivalves occur in deep water and have been dredged at depths of 100 m.

G. oahuana was described from the Hawaiian Islands. The valves are distinguished from those of *G. cuneiformis* in that they lack the anterior beak.

Family **Hiatellidae**

(= **Saxicavidae**)

The members of this family have soft, crumbling, often distorted shells with gaping valves indicative of their boring or nestling habits. Most hiatellid shells are white or gray and there are two small cardinal teeth on the hinge.

Hiatella arctica (Linnaeus, 1767). Fig. 185 F, G. (Synonym: *Saxicava hawaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 4 mm; length, 6 mm; diameter, 3 mm. *Shell:* oval, distorted; thin and flaking; inequilateral, beaks anterior to the midline; with concentric lamellae; cream to white. *Margins:* dorsal line almost straight; ventral margin slightly curved; anterior and posterior ends rounded. *Hinge:* ligament strong, external; cardinal teeth merely indicated. *Sculpture:* irregularly developed and disposed concentric lamellae. *Color:* cream or white.

These bivalves are nestlers, attached by the byssus in holes and crevices in tide pools and forming mats on the substrate in certain areas at Pearl Harbor, Oahu.

Hiatella is notoriously variable, and Lamy (1924), Dell (1964), Strauch (1968) and Beu (1971) suggest a near-cosmopolitan distribution for a single species which has been assigned a variety of names. In temperate and arctic waters individuals reach sizes of 40 to 50 mm (Strauch, 1968; Dell, 1964); in warmer waters shells are much smaller. The Hawaiian shells distinguished by Dall, Bartsch, and Rehder (1938) as a distinct species fall within the range of variability recognized in the cosmopolitan species.

Superfamily PHOLADACEA

Family **Pholadidae**

Pholads are specialized borers in hard substrates and are among the most highly modified of all bivalves. They have a suckerlike foot and well-developed siphons.

The pholads, like the shipworms, are wood borers and at least one species is widely distributed throughout the Pacific and Atlantic oceans. Pholad shells are more or less elongated and posteriorly narrowed, gape broadly anteriorly and posteriorly, and the surface is radiately or concentrically sculptured. There is neither ligament nor hinge area, and the valves are held together by muscles. The shells of pholads are usually white.

Martesia striata (Linnaeus, 1758). Fig. 185 C. (Synonym: *Martesia hawaiensis* Dall, Bartsch, and Rehder, 1938.) Height, 15 mm; length, 32 mm. *Shell:* wedge-shaped, gaping, brittle; with concentric sculpture; white. Of three accessory plates, the mesoplax dorsal, irregular in outline; metaplax broadly elliptical, fitting anteriorly under mesoplax; hypoplax ventral, elliptical. Sculpture of concentric ridges divided by parallel ridges running from anterior border to umbonal area.

This species has been cited as causing some damage to wooden structures in Pearl Harbor, Oahu (Kofoid and Miller, 1927), and burrows attributed to *M. striata* were found in test blocks in Nawiliwili Bay, Kauai (R. C. Miller, 1924).

M. striata is widely distributed throughout the Atlantic and Pacific oceans (Turner, 1955).

Family **Teredinidae**

The teredoes or shipworms are notorious for their habit of boring in wood: they invade new wood during their short, free-swimming larval period by boring a minute hole, and within a few months honeycomb the wood with burrows (Fig. 186 B) which may be several meters in length. The wood-boring habit and the habit of many of bearing larviparous young have resulted in their dispersal over vast areas of the ocean.

These bivalves have a short, gaping shell which covers only the anterior end of an elongate body. The posterior extremity, which remains at the surface of the wood, terminates in two slender tubes or siphons, at the base of which is a pair of calcareous structures, the pallets (Fig. 187 A). The shell (Fig. 187 B) consists of two somewhat triangular valves composed of an anterior portion with rows of denticulated ridges, and a more or less smooth posterior part or auricle. A large muscular foot protrudes through the gape in the valves and acts as a suction disk, holding the valves against the sides of the burrow. The long, wormlike body lies in the tubular burrow which is lined by a smooth calcareous glaze.

Teredo shells are enormously variable and cannot be utilized to distinguish even genera; the pallets, on the other hand, are useful in both generic and specific diagnoses. In *Bankia* the elongate pallets are composed of numerous cone-shaped elements supported on a stalk which extends the length of the blade (Fig. 188 A). In *Lyrodus* there is a calcareous base at the lower end of the pallets (Fig. 188 B-G), and the pallets are brown and lack a periostracal cap. The pallets in *Teredo* are entirely calcareous, with the blade in one piece and a small cup which may be divided medially (Fig. 189); the periostracum is usually thin and adheres to the calcareous portion of the blades.

The destructiveness of shipworms in Hawaiian waters has long been recognized, and it has been suggested that the period of usefulness of untreated timbers exposed to the sea in the Hawaiian Islands is usually less than two years (Edmondson, 1942). The first systematic investigations of Hawaiian teredoes were those of Bartsch (1921) and R. C. Miller (1924). Their work was followed by the extensive investigations of Edmondson (1942, 1946b, 1962) and Edmondson and Ingram (1939) on fouling organisms in the Hawaiian Islands.

The synonymies used here are those of Turner (1966).

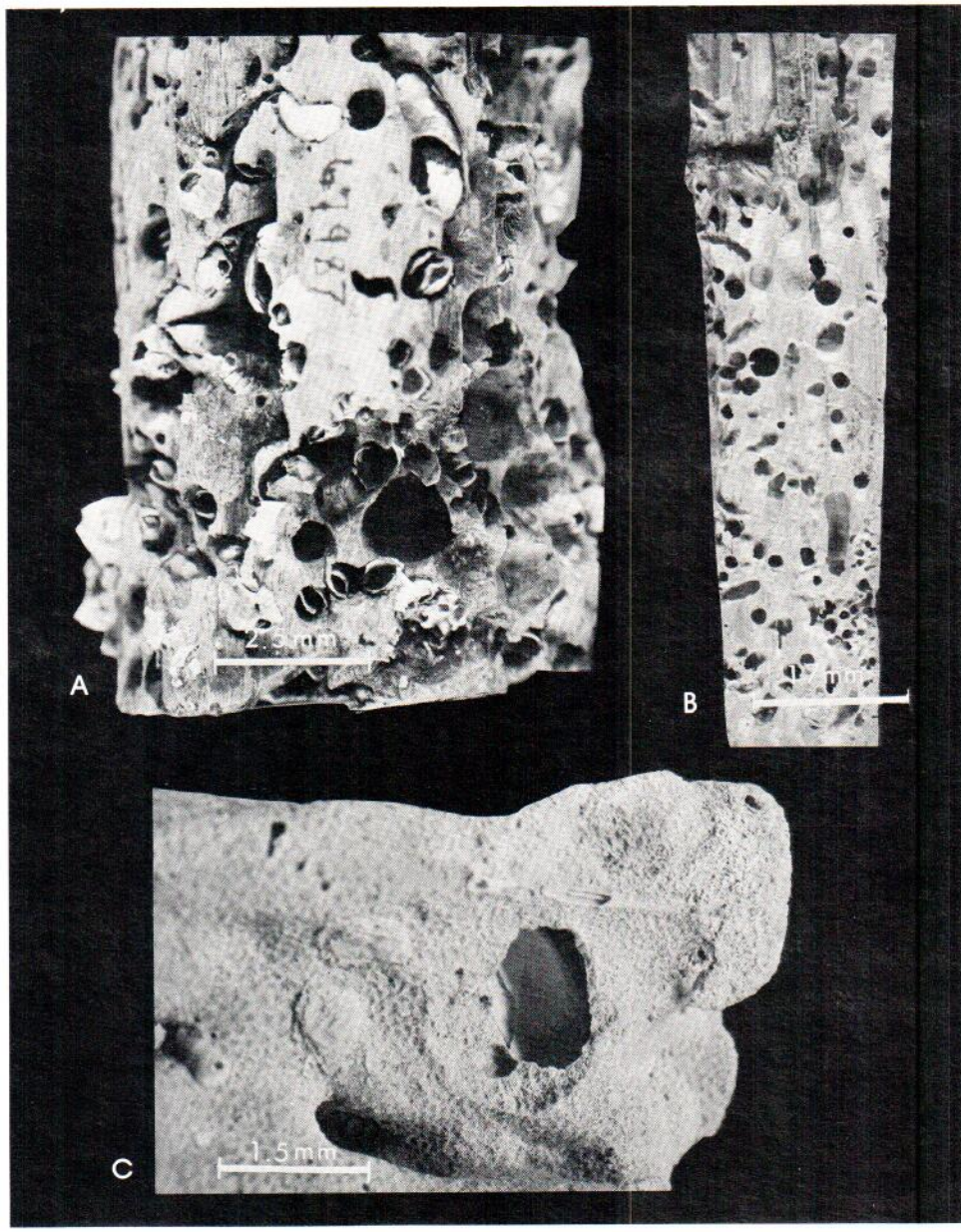


Figure 186.—Some boring bivalves and their effects. A. Piece of wood with *Martesia striata*. B. Piece of wood riddled with *Teredo*. C. Piece of coral with *Gastrochaena* sp.

Bankia bipalmulata (Lamarck, 1801) Fig. 188 A. (Synonyms: *Bankia hawaiiensis* Edmondson, 1942; *B. konaensis* Edmondson, 1942.) Pallets of cone-shaped elements on a long stalk, the free edge of one side serrated.

This is a common species in the Hawaiian Islands; the animals may attain a length of 2 feet.

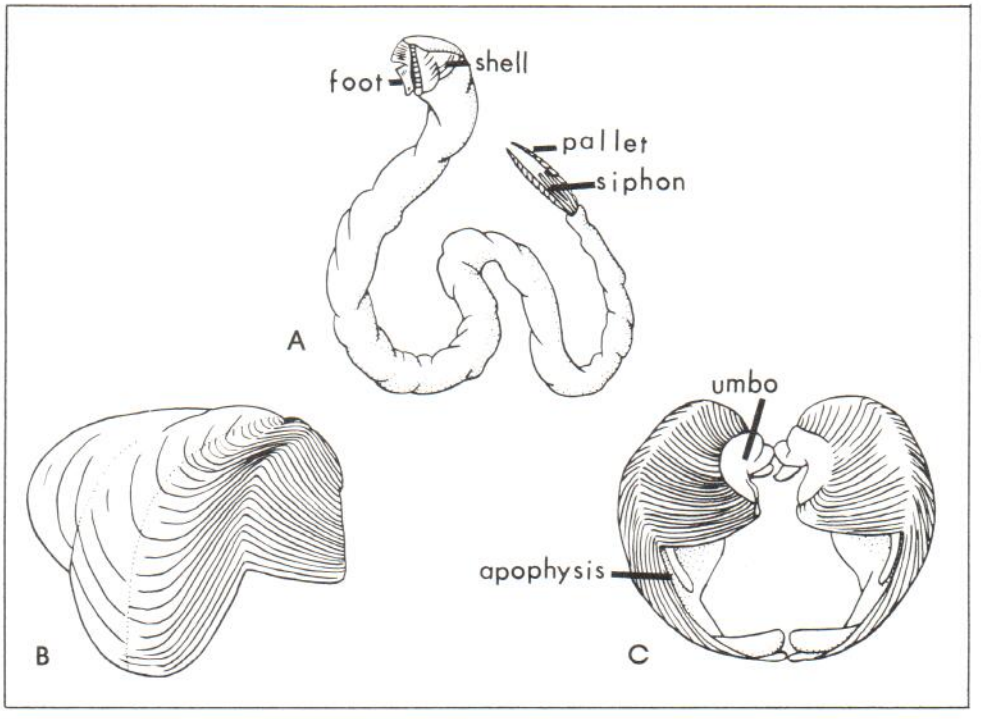


Figure 187.—A. Diagrammatic sketch of a teredinid. B. Shell of a teredinid. C. Valves in anterior view. (After Turner, 1966.)

Lyrodus affinis (Deshayes, 1863). Fig. 188 B-D. (Synonym: *Teredo milleri* Dall, Bartsch, and Rehder, 1938.) Pallets with a long, slender stalk; blade of a short, urn-shaped base surmounted by a dark brown, chitinous distal portion.

L. affinis is a common species widely distributed among the Hawaiian Islands.

Lyrodus medilobata (Edmondson, 1942). (Not figured.) Pallets with a median lobe on the distal portion; siphons lack color spots and there is no collar or thickening at the base (Turner, 1966).

Edmondson (1942) collected *L. medilobata* in Honolulu Harbor and at Waikiki.

Lyrodus pedicillatus (Quatrefages, 1849). Fig. 188 E-G. (Synonyms: *Teredo hawaiensis* Dall, Bartsch, and Rehder, 1938; *T. honoluluensis* Edmondson, 1946; *T. kauaiensis* Dall, Bartsch, and Rehder, 1938; *T. midwayensis* Edmondson, 1946b.) Pallets with a long, broad, paddle-shaped blade, the anterior three-fourths covered with a strong amber or black periostracal cap. Shell length, 1.8 mm; height, 2 mm.

L. pedicillatus is found throughout the world in tropic and temperate seas.

Teredo bartschi Clapp, 1923. Fig. 189 A-C. (Synonym: *Teredo hiloensis* Edmondson, 1942.) Pallets with a straight-sided blade terminating in sharp points and stout stalk, shorter than blade; blade convex on outer surface, flattened on inner face, capped by a red-brown periostracum. Shell length, 4 mm; height, 4 mm.

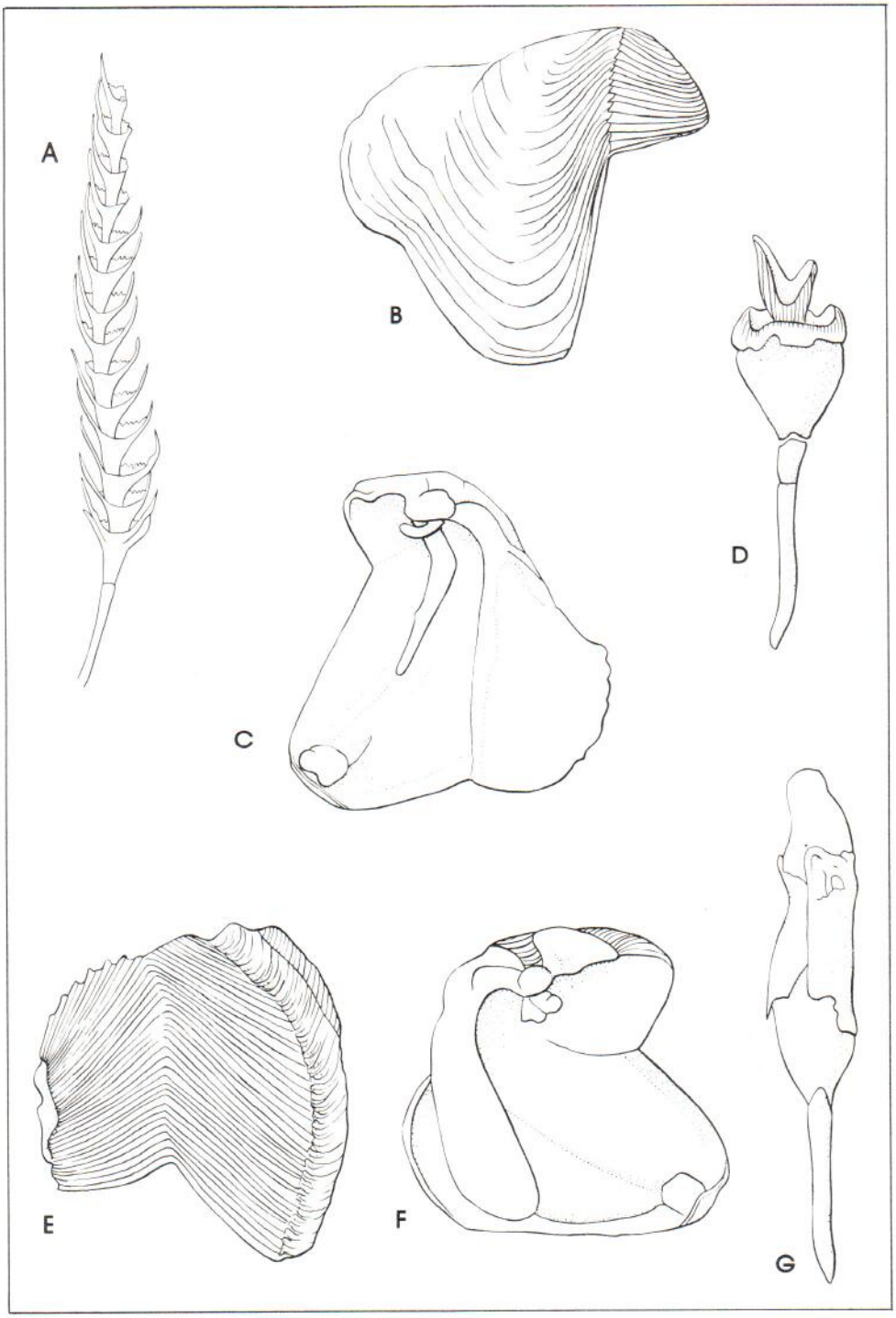


Figure 188.—**Teredinidae.** A. *Bankia bipalmulata,* outer face of pallet. B, C, D. *Lyrodus affinis,* shells and outer face of pallet. E, F, G. *L. pedicillatus,* shells and outer face of pallet. (All after Turner, 1966.)

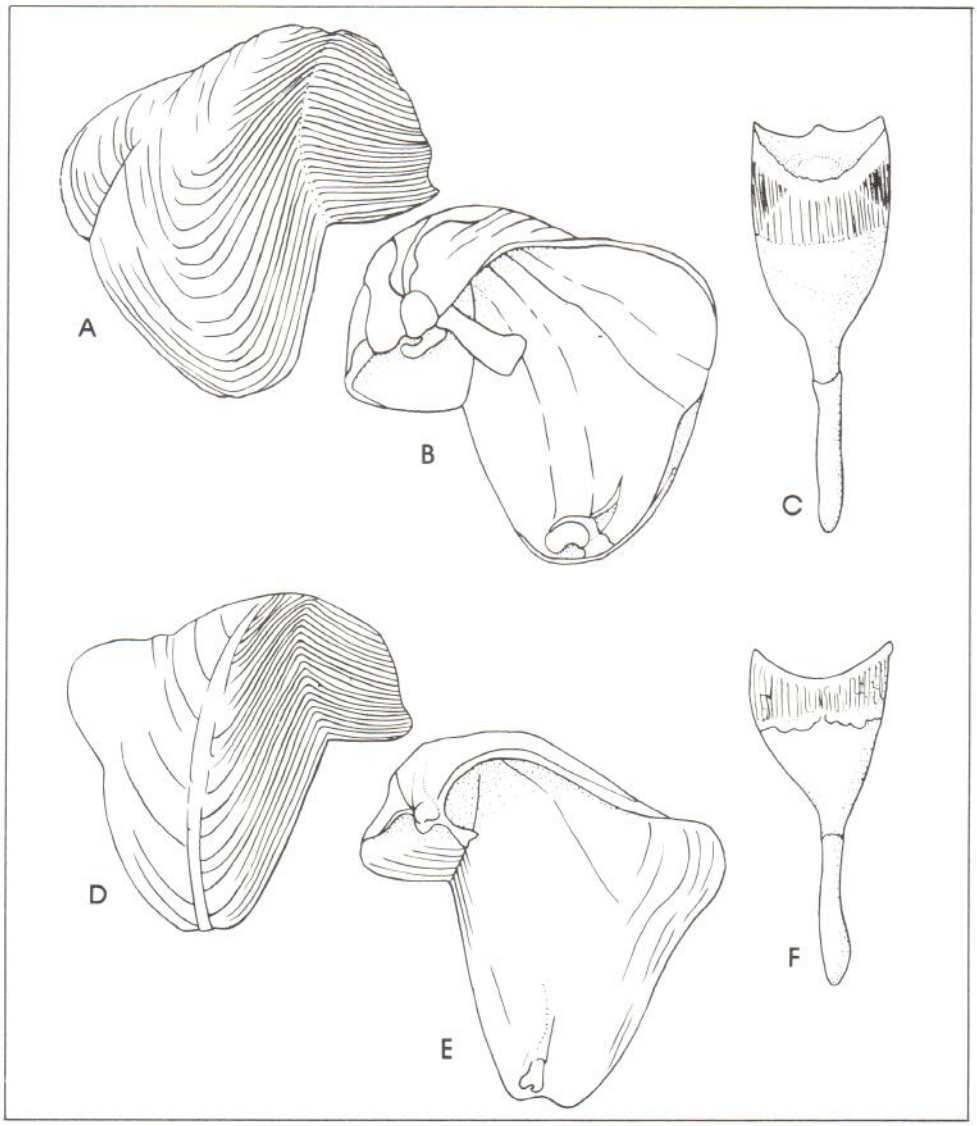


Figure 189.—A - C. Shells and pallet of *Teredo bartschi*. D - F. Shells and pallet of *T. clappi*. (After Turner, 1966.)

T. bartschi was described from Port Tampa, Florida, and is apparently worldwide in its distribution. Edmondson described *T. hiloensis* from Hilo, Hawaii, and also found specimens in Honolulu Harbor.

Teredo clappi Bartsch, 1923. Fig. 189 D-F. (Synonym: *Teredo trulliformis* Miller, 1924.) Pallets with a short, broad blade and expanded stalk; distal portion of blade with a gray or brown epidermis and extremity with a crescent-shaped excavation. Shell length, 3.4 mm; height, 3.2 mm.

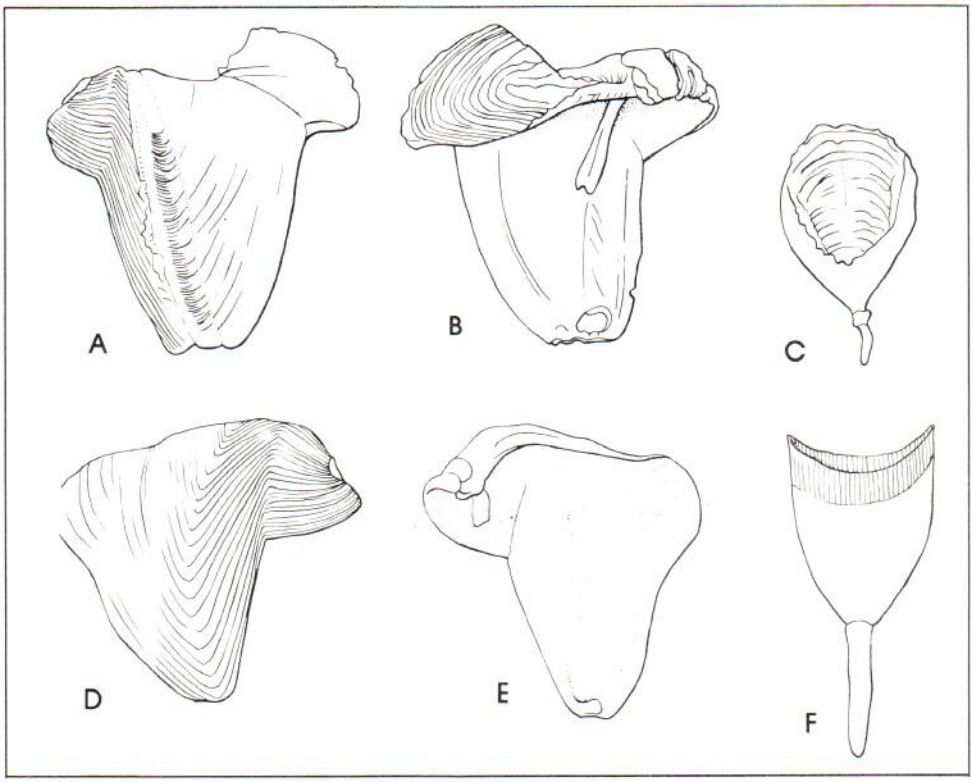


Figure 190.—A - C. Shells and pallet of *Teredo princesae*. D - F. Shells and pallet of *T. triangularis*. (After Turner, 1966.)

This is a common species in Kaneohe Bay, Oahu. Settling of larvae is continuous throughout the year, with a peak in the warmer fall months (Uchiyama, 1963). The settling period occurs within four days after the veligers are released and the teredo matures in less than two months (Uchiyama, 1963). A narrow, elongate, white polyclad, *Taenioplana teredini* Hyman, 1944, is sometimes found in the burrows.

T. clappi was described from Key West, Florida, and the species is widely distributed.

Teredo furcifera von Martens, 1894. (Not figured.) (Synonyms: *Teredo furcillatus* Miller, Dall, Bartsch, and Rehder, 1938; *T. bensoni* Edmondson, 1946b; *T. parksi* Bartsch, 1921.) Pallets with a long stem and small blade, variable in shape, distal portion deeply excavated on outer and inner face. Shell length, 3.4 mm; height, 3.3 mm.

This species was the dominant teredinid in all test blocks except those set at Nawiliwili, Kauai in 1924 (R. C. Miller, 1924) and is thought to be the prevailing species in Hawaiian waters (Edmondson, 1946b). Breeding activity as indicated by settlement of larvae reaches a maximum in August, September, and October, and progressively decreases from November to March, reaching a minimum in April (R. C. Miller, 1924).

T. furcifera was described from the Moluccas Islands and has also been recorded from Ceylon and Madagascar (Turner, 1966).

Teredo princesae Slvickis, 1928. Fig. 190 A-C. (Synonym: *Teredo gregoryi* Dall, Bartsch, and Rehder, 1938.) Pallets spoonshaped, stalk short and slender. Shell length, 12.3 mm; height, 14.6 mm. The burrows of these teredoes may reach a diameter of 18 mm and a length of 60 cm (Edmondson, 1946b).

T. princesae was described from the Philippines.

Teredo triangularis Edmondson, 1942. Fig. 190 D-F. Pallets with a heavy, triangular blade. Shell length, 5.5 mm; shell height, 7.5 mm.

This teredo is common at Kahului, Maui, and elsewhere in the Hawaiian Islands (Edmondson, 1942).

Additional Records

Turner (1966) suggests that *Teredo oahuensis* Edmondson, 1942, is a young *Nausitora;* Edmondson (1946b) notes that it is a rare species.

Superfamily PANDORACEA

Family **Lyonsiidae**

These bivalves have rather small, brittle or fragile, white shells which are elongate-ovate in shape and usually gape ventrally. The surface is covered with radial rows of fine microscopic spines or nodules which are often worn off, and there are also rugose concentric wrinkles on the surface. The ligament is internal and the hinge toothless. The shells are inequivalve and the pallial sinus is distinct.

Lyonsia oahuensis Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 12 mm; length, 22 mm; diameter, 9 mm. *Shell:* oval, thin and fragile; with low rounded cords radiating toward the ventral margin; horn-colored. *Margins:* beaks elevated; dorsal line slightly arcuate; anterior end rounded, forming a beak at the junction with the ventral margin; ventral edge waved by concentric sculpture. *Hinge:* ligament internal, on a shelf posterior to the beaks; hinge without teeth. *Sculpture:* strong, low rounded cords and wrinkles radiating toward the base and microscopic granules. *Color:* horn-colored.

This is a deep-water form, and shells were dredged by the *Albatross* at depths of between 500 and 600 m.

L. oahuensis was described from the Hawaiian Islands.

Superfamily POROMYACEA

The members of this superfamily have been considered a separate order, the Septibranchia, because of their carnivorous and scavenging habits. The gill is modified

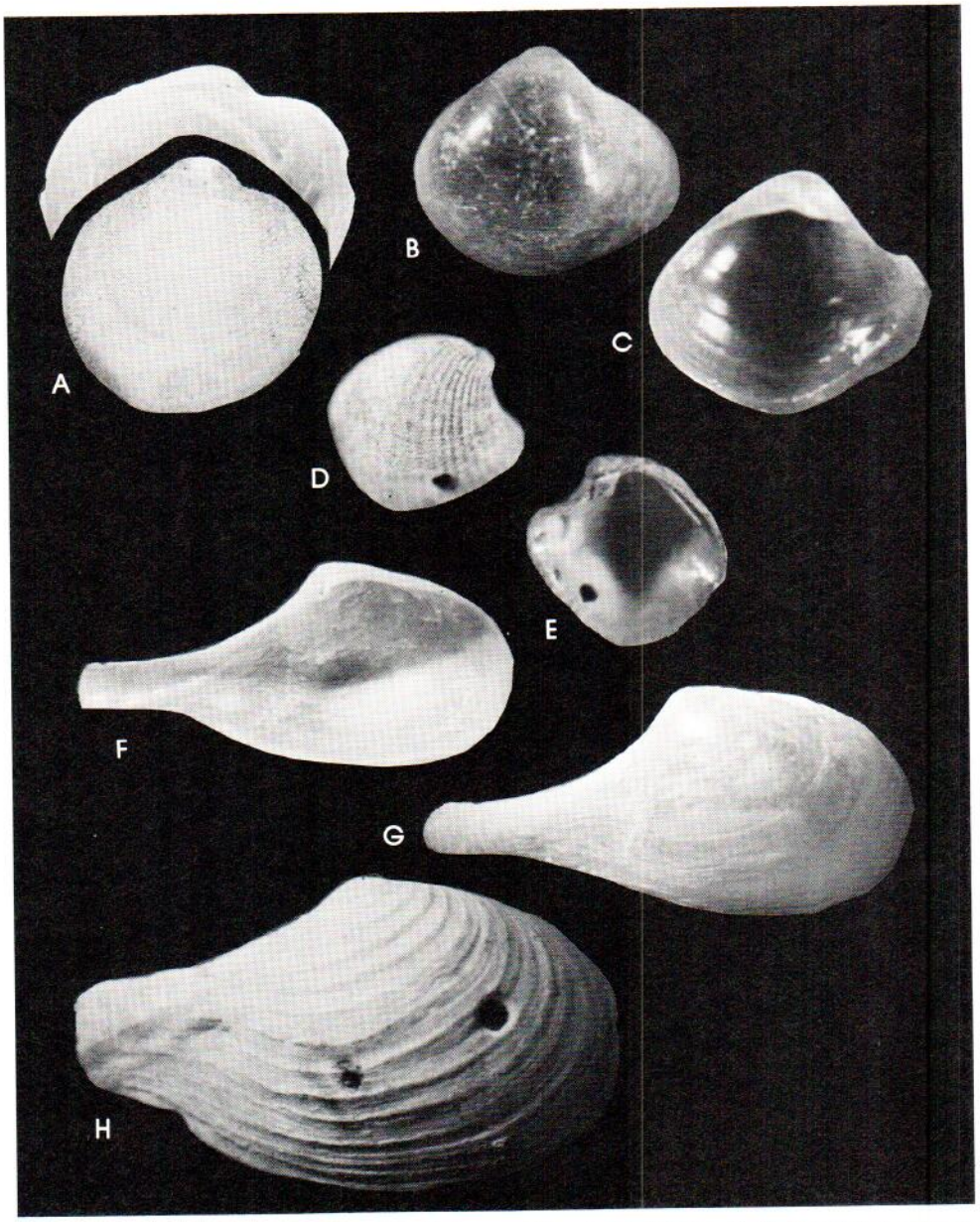


Figure 191.—Deep water bivalves. A. *Euciroa pacifica*, length 25 mm. B, C. *Poromya transversa*, length 11 mm. D, E. *Policordia diomedea*, length 5 mm. F, G. *Cuspidaria hawaiensis*, length 14 mm. H. *C. pailoloana*, length 6 mm.

as a perforated muscular septum which pumps water containing small crustacea and annelids through the pallial cavity. These bivalves are mostly found in deep water where they burrow into soft mud by means of the thin, wedgelike foot.

The shells are white or gray, weakly sculptured, and fragile.

Family **Cuspidariidae**

In this family the shell is markedly inequilateral, with the posterior region drawn out into a projecting beak. The shells are thin and inflated, the ligament is internal, and there may be cardinal teeth on the hinge line. The pallial line is simple and the siphons are united.

Cuspidaria dispar Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 10 mm; length, 14 mm; diameter, 3 mm. *Shell:* ovate, posterior edge barely beaked; beaks submedian; with two radiating keels; white. *Margins:* beaks moderately prominent; posterior margin drawn out slightly; anterior edges rounded, ventral margin sinuated by two keels radiating from the posterior edge of the umbo. *Hinge:* ligament thin; hinge without teeth. *Sculpture:* low, rounded, equally spaced concentric ridges from the first keel to the anterior edge, remainder of shell with fine incremental lines. *Color:* white.

These bivalves were dredged by the *Albatross* at depths of 550 to 1000 m.

C. dispar was described from the Hawaiian Islands.

Cuspidaria hawaiensis Dall, Bartsch, and Rehder, 1938. Fig. 191 F, G. Height, 11 mm; length, 22 mm; diameter, 10 mm. *Shell:* oval, decidedly beaked posteriorly; with concentric threads; white. *Margins:* beaks moderately elevated, broad; anterior and ventral margins rounded. *Hinge:* ligament internal; right valve with a posterior lateral tooth. *Sculpture:* concentric threads of varying strength, forming transverse threads on the beak. *Color:* white.

This is the most commonly occurring of the cuspidarias, and numerous specimens have been dredged at depths of 560 to 850 m.

C. hawaiensis was described from the Hawaiian Islands.

Cuspidaria pailoloana Dall, Bartsch, and Rehder, 1938. Fig. 191 H. Height, 9 mm; length, 15 mm. *Shell:* shell ovate; posterior moderately beaked; with thin, regularly spaced concentric lamellae; white. *Margins:* beaks prominent and moderately projecting; anterior and ventral margins curved. *Hinge:* ligament internal; hinge without teeth. *Sculpture:* regularly spaced thin, concentric lamellae. *Color:* white.

This species is known from two valves dredged by the *Albatross* at depths of 560 to 660 m.

C. pailoloana was described from the Hawaiian Islands.

Family **Poromyidae**

The shells in this family are suborbicular, thin, inflated, and gray or white. They are equilateral, with prominent umbones. The surface is covered with minute granules arranged in radiating rows. The ligament is external and posterior; there may be a well-developed tooth on the right valve.

Poromya transversa Dall, Bartsch, and Rehder, 1938. Fig. 191 B, C. Height, 7 mm; length, 8 mm; diameter, 3 mm. *Shell:* ovate, inflated; with spinous radiating ribs; gray-white. *Margins:* umbones elevated; dorsal margin curved; posterior edge

obscurely beaked; ventral margin rounded. *Hinge:* ligament external; right valve with a weakly developed cardinal tooth. *Sculpture:* closely spaced, radiating lines of short spicules, and faint incremental lines. *Color:* gray white; periostracum thin, straw-colored.

This species was described from a single valve dredged by the *Albatross* at a depth of 532 m.

P. transversa was described from the Hawaiian Islands.

Family **Verticordiidae**

These are deep water bivalves with rather thin, inflated shells which are small to medium in size. They are white or gray and covered with a brownish periostracum. The surface is minutely granular with the granules or blunt spines arranged in radiating rows. There may be cardinal or lateral teeth on the hinge.

Euciroa pacifica Dall, 1895. Fig. 191 A. Height, 26 mm; length, 28 mm; diameter, 20 mm. *Shell:* suborbicular, thin, inflated; equivalve and equilateral; with radiating rows of short spines; white. *Margins:* beaks prominent and directed anteriorly; anterior, posterior, and ventral margins curved. *Hinge:* ligament short, in a groove; right valve with a strong, pointed, slightly curved cardinal tooth and a sublamellar, low lateral; left valve with three low cardinals. *Sculpture:* numerous, regularly spaced rows of short spicules. *Color:* exterior white; periostracum thin, yellow; interior pearly white and radially striated.

This is the most abundant of the deep water bivalves at depths of from 560 to 1000 m.

E. pacifica was described from the Hawaiian Islands.

Halicardia gouldi Dall, Bartsch, and Rehder, 1938. (Not figured.) Height, 32 mm; length, 30 mm; diameter, 25 mm. *Shell:* rhomboidal, thin, fragile; equivalve and equilateral; with nodulated radiating threads; white. *Margins:* beaks prominent and curving anterior; anterior and posterior portions of the shell developed as wings; posterior region separated by an impressed groove; ventral margin straight, produced at junction with anterior edge. *Hinge:* ligament internal in a groove; right valve with an obscure tooth. *Sculpture:* numerous closely spaced nodular radiating threads and concentric threads. *Color:* white; periostracum thin, yellow; interior dull pearly.

The unique type was dredged by the *Albatross* in deep water but with no designation of depth.

H. gouldi was described from the Hawaiian Islands.

Policordia diomedea Dall, Bartsch, and Rehder, 1938. Fig. 191 D, E. Height, 10 mm; length, 9 mm; diameter, 6 mm. *Shell:* subglobular, thin; with slender radiating and concentric threads; translucent. *Margins:* beaks prominent, anteriorly incurved; dorsal line curved and forming an angle with the anterior margin; anterior, posterior, and ventral margins curved. *Hinge:* ligament internal; hinge without teeth. *Sculpture:* slender, radiating threads and microscopic concentric growth lines. *Color:* translucent; periostracum thin, horn-colored; interior pearly and showing external sculpture.

Valves of *P. diomedea* were dredged by the *Albatross* at depths of 568 to 580 m.

This species was described from the Hawaiian Islands.

Class POLYPLACOPHORA

The chitons are elongate, usually flattened, bilaterally symmetrical mollusks with a shell consisting of eight separate, overlapping plates held in position by a peripheral muscular girdle. Neither a distinctive head nor tentacles is present. The sensory organs consist of the subradular organ, a chemoreceptor that "tests" the substrate over which the mouth moves, megalasthetes or "eye spots" on the surface of the valves, and sensory streaks in the mantle cavity. A narrow pallial groove extends between the foot and the girdle; it is divided into inhalant and exhalant chambers by a series of ctenidia. Anatomically the chitons exhibit a number of features which are considered primitive among mollusks: symmetrically arranged excretory and reproductive organs; a simplified gut; and lack of conspicuous ganglia in the nervous system. The sexes are separate and fertilization is external.

These mollusks are adapted to life on hard substrates, and are often found on rocky, surf-beaten shores; some have been dredged from depths of more than 2000 m (Keen, 1971). The broad foot enables them to adhere to the substrate and the articulating shell valves (Fig. 192 E, F) permits the animals to conform to irregular hard surfaces. They browse over the substrate with a broad radular ribbon, the teeth of which are capped with a very hard mineral, magnetite.

Classification is based on the radula and valve structure and sculpture.

Family **Acanthochitonidae**

In this family the valves are partially to completely buried in the girdle, and the insertion plates of the terminal valves have few slits. The girdle bears tufts of spines.

Acanthochiton armata (Pease, 1872). Fig. 192 C. Length, 10 mm; diameter, 6 mm. Elongate oval. Light green spotted with black; foot orange-red. Girdle with silvery white spicules. Lateral areas of valves granulose.

These chitons are found on surf-beaten shorelines, often under the stipes of the red alga *Ahnfeltia*.

A. armata was described from the Hawaiian Islands, and has been reported from Taiwan (Wu, 1969).

Acanthochiton viridis (Pease, 1872). Fig. 192 B. Length, 28 mm; width, 10 mm. Ovate, slightly elevated. Green with a pale line down the middle. Girdle densely covered with small, dark-colored cylindrical spines and prominent tufts of long spicules. Head valve with five slits, median valves with a single slit on each side, tail valve with two slits.

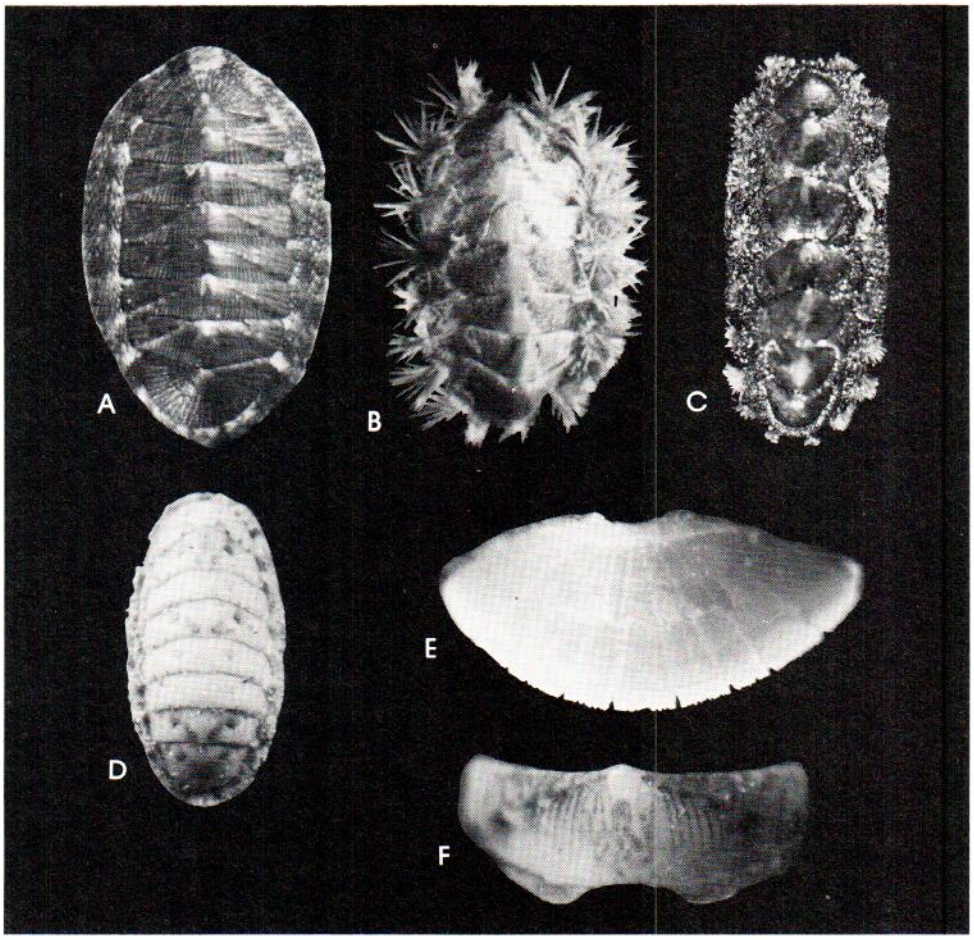


Figure 192.—A. *Rhyssoplax linsleyi*, length 13 mm. B. *Acanthochiton viridis*, length 28 mm. C. *A. armata*, length 10 mm. D. *Ischnochiton petaloides*, length 8 mm. E, F. Insertion plates of chitons.

These chitons are found in holes and under rubble in tide pools on surf-beaten coastlines.

A. viridis was described from the Hawaiian Islands.

Family **Chitonidae**

The insertion plates in the Chitonidae have well-developed pectinations which may be coarsely grooved to fine and comblike. The girdle is scaly, nude, or with spicules or bristles.

Rhyssoplax linsleyi Burghardt, 1973. Fig. 192 A. Length, 13 mm; width, 8 mm. Small, broadly oval. Color variable — gray-white, black and white, or green and white. Girdle with fairly large, smooth scales. Surface of valves smooth except for a series of shallow grooves. Dorsal ridge smooth and shiny; valves beaked. Jugal area

smooth. Anterior valve with eight slits on the outer edge of the insertion plate, edge finely pectinate. Outer margins of insertion plates pectinate, with a single slit. A distinguishing feature is a color pattern of marks, shaped like small sunbursts which "pit" the smooth surface of the valves.

These chitons are found at the base of boulders from the intertidal to depths of 5 m. The young are brooded in the pallial cavity (Burghardt, 1973).

R. linsleyi was described from the Hawaiian Islands.

Family **Ischnochitonidae**

This family includes a series of generalized chitons with scaly girdles and simple insertion plates. The intermediate valves are divided into lateral and central areas by a diagonal rib (sometimes obsolete). The head and tail valves are multislitted, and the intermediate valves have one or two slits on each side.

Stenoplax [=Ischnochiton] *petaloides* (Gould, 1846). Fig. 192 D. Length, 10 mm; width, 4 mm. Oval. Color variable — yellow, blue, dark green, or gray, off-white margined with orange. Girdle with minute, imbricating scales. Valves keeled longitudinally on the midline, posterior valve with a transverse rib; central areas of valves somewhat rugose and punctate, lateral areas granulated and with a few radiating striae. Tail valve with a well-developed mucro.

These chitons are common, found under rocks in tide pools and in shallow areas shoreward on fringing reefs.

This species was described from the Hawaiian Islands.

Class SCAPHOPODA

The scaphopods are carnivorous, burrowing mollusks with a long, tapered shell open at both ends. In life these mollusks lie buried in sand or gravel with the broad end of the shell containing the head and foot lying deepest and the tapered end projecting from the substrate (Morton, 1967). There is a strong, plug-shaped or vermiform foot by means of which the animals burrow. They feed primarily on foraminiferans captured by ciliated tentacles, the captacula, borne on the head. The radula is well developed and grinds the food into small pieces (Bilyard, 1974).

In Hawaiian waters scaphopods are found at depths of more than 60 m. At least two families are represented, the Dentaliidae with curved, tapering, longitudinally sculptured shells and the Cadulidae (*sensu* Palmer, 1974) with small, smooth shells constricted at the aperture. The three species described from Hawaii are briefly distinguished below; several other species remain to be identified.

SPECIES	DIMENSIONS	DESCRIPTION
Family Dentaliidae		
Dentalium complexum Dall, 1895 (Fig. 193 F)	length, 78 mm; anterior diameter, 8.5 mm	white, glossy; nearly straight; sharply grooved with interspaces varying in size
D. phaneum Dall, 1895 (Fig. 193 E).	length, 35 mm; anterior diameter, 2.2 mm	pale straw; nearly straight; with longitudinal threads and wider, flat, transversely feebly striated, glassy-surfaced interspaces
Family Cadulidae		
Cadulus honoluluensis Watson, 1880	length, 12 mm; anterior diameter, 1.5 mm.	transparent, white; slightly swollen in the middle; anterior end constricted

Class CEPHALOPODA

The cephalopods with their complex nervous system, highly developed eyes, long, sucker-studded arms, and powerful beaks and radulae are specialists in rapid movement and efficient hunting. They are not only considered among the most advanced of all mollusks but they are also among the oldest, with a fossil record dating back about 450 million years.

There are two subclasses, the Nautiloidea which includes *Nautilus* (not represented in Hawaiian waters) with a chambered, external shell and two pairs of gills, and the Coleoidea to which all other living cephalopods are assigned. The Coleoidea have a single pair of gills, eight or ten arms, and an internal shell is present in some forms.

The Hawaiian cephalopods were monographed by Berry (1914) who described and/or recorded 33 species, including pelagic forms collected from Hawaiian waters during the *Albatross* expedition. Recent studies of pelagic cephalopods (see Roper and Young, 1975; Young, 1972a, 1972b, 1975a, 1975b) have added substantially to Berry's work. Only the benthic cephalopods and a pelagic squid found in shallow water are reported here.

Order SEPIOIDEA

This group of cephalopods includes the cuttlefish (Family Sepiidae) and *Spirula*, the peculiar pelagic form which can descend to great depths of the ocean with its unique, coiled, internal shell. Neither is represented in Hawaiian waters, but a benthic sepiolid is common.

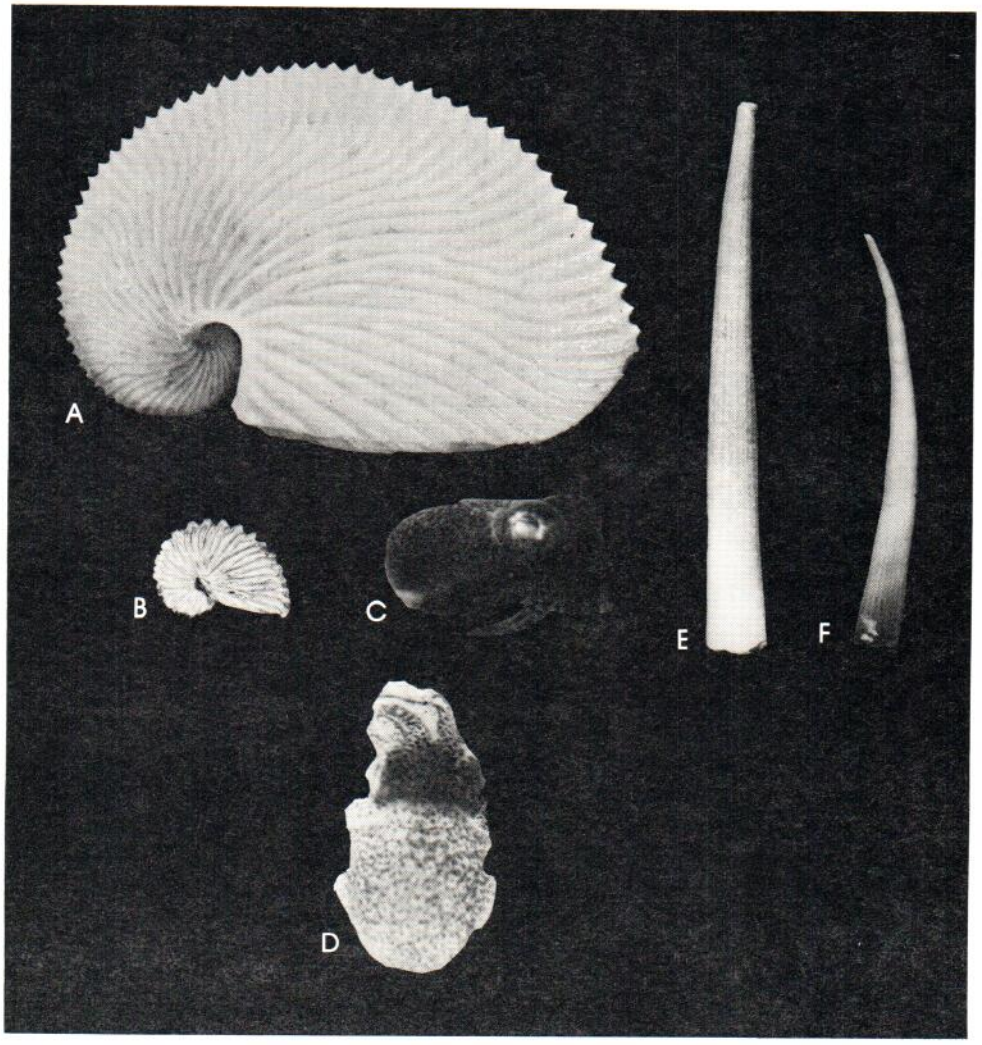


Figure 193.—A. *Argonauta argo*, diameter 94 mm. B. *Argonauta bottgeri*, diameter 40 mm. C, D. *Euprymna scolopes*, length 20 mm. E. *Dentalium phaneum*, length 80 mm. F. *D. complexum*, length 20 mm.

Family **Sepiolidae**

The sepiolids have short, thick, rounded bodies, with large fins attached laterally near the middle of the body. Some are wholly pelagic, others are benthic or quasipelagic and spend much of their time buried in the substrate (Roper and Young, 1975).

Euprymna scolopes Berry, 1913. Fig. 193 C, D. Length, 30 to 50 mm (including arms). *Animal:* body short, rounded posteriorly, with round or ovate lateral fins; arms short and stout with two rows of suckers at the base and four toward the extremities. *Color:* pale brown, sometimes spotted with darker brown.

These animals are common in shallow water on sand and mud flats in Kaneohe Bay, Oahu, where they forage, feeding on the shrimp *Leander debilis*, at depths of less than half a meter (Arnold and others, 1972). Eggs are laid at night and attached to rocks or loose pieces of coral; animals hatched in the laboratory are sexually mature in 183 to 202 days (Arnold and others, 1972).

Order TEUTHOIDEA

The Teuthoidea comprise the squid, the *mūhe'e* of the Hawaiians. They are streamlined animals which are perpetual swimmers. There are eight arms surrounding a pair of tentacles which are usually much longer than the arms and retractile into two pockets in the head region.

Family **Loliginidae**

Loliginids are pelagic in habit, with elongate, cylindrical bodies and marginal or terminal fins. The suckers are attached to the arms and tentacles by short, muscular stalks. The skeleton consists of a thin, chitinous "gladius" lying within the body and to which the muscles are attached. Members of the family appear to be neritic, found in coastal waters rather than in deep water (Roper and Young, 1975).

Sepioteuthis lessoniana Lesson, 1830. (Not figured.) (Synonym: *Sepioteuthis arctipinnis* Gould, 1852.) *Length of mantle:* 160 to 190 mm. *Animal:* elongate-conical, compressed dorsoventrally, tapering to a blunt point posteriorly; mantle thick and heavy, anterior margin free; fins marginal, extending the length of the animal. *Color:* gray to brown.

S. lessoniana is the *mūhe'e* or common squid of the market in Hawaii. The squid are caught in nets by fishermen, and more than 9,000 pounds are sold annually.

Order OCTOPODA

Octopods have eight arms, as their name implies, and are distinguished from other cephalopods by their sessile, rather than stalked suckers. In contrast to the squids, they have evolved as bottom-living animals with saclike bodies and no skeletal support. There are two suborders, the Cirrata or finned octopods which include both benthic and pelagic forms, and the Incirrata, octopods without fins. As far as is known, all shallow-water benthic octopods attach their eggs to some solid substrate,

usually rocks, coral or shells, and after depositing the eggs, the female broods them until hatching.

Family **Argonautidae**

The well-known thin, papery shell of the argonauts or paper nautilus is not homologous with the shells of other mollusks, but is a specialized structure secreted by the first pair of arms of the female argonaut. The shell functions as a brood pouch in which the young develop, and as a flotation device. In aquaria argonauts can leave their shells and crawl like other octopods; in the open sea, however, they swim within the shell by jet propulsion. The male argonaut is much smaller than the female, less than 5 mm in length. The male deposits an entire arm (the hectocotylus) laden with sperm in the mantle cavity of the female.

Argonauta argo Linnaeus, 1758. Fig. 193 A. *Diameter:* 90 mm. *Shell:* compressed, keel and aperture narrow; sides with numerous simple and bifurcate ribs, most extending from the columella to the carinal knobs, a few of the outer ones separate, forming secondary ribs; keel with two rows of low, sharp, numerous, closely spaced tubercles; sides of shell forming outward projections or "ears." *Color:* shining white, carinal tubercles brown.

Empty shells are infrequently cast up with drift on Oahu and Lanai.

A. argo is a cosmopolitan species in warm and temperate seas.

Argonauta bottgeri Maltzan, 1881. Fig. 193 B. Diameter, 40 mm. *Shell:* compactly coiled on an even plane, laterally compressed; sides ornamented with 30 or more conspicuous ridges radiating from the columella; periphery flattened, each angle decorated with a row of bluntly squared tubercles; margins of aperture simple, without any trace of lateral expansions or auricles; surface finely and evenly granulose, the granules most numerous near the axis. *Color:* white.

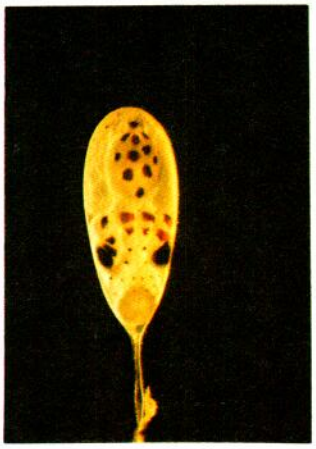
These small argonauts form a rather minor part of the diet of the bigeye and yellowfin tunas (King and Ikehara, 1956), and shells have been found in the stomach of mahimahi *(Coryphaena hippurus).*

A. bottgeri is distributed throughout the Indo-West Pacific from Mauritius to Hawaii.

Family **Octopodidae**

The familiar octopus which occurs in shallow water has a short, thick, firm, muscular body. The eight arms, each with suckers placed in precise rows, possess a discriminating sense of touch. The skin is studded with chromatophores, by means of which the animals change color, and there is a general tendency for octopods to resemble the background against which they live.

Octopus cyanea Gray, 1849. Fig. 194 A-E. (Synonym: *Octopus marmoratus* Hoyle, 1886.) Length to 180 mm; weight to 5.6 kgm. *Animal:* rounded-pyriform, broadest posteriorly, with a distinct median longitudinal depression on the ventral surface; head small, narrow, rounded, separated from the body by a slight constriction;



A

B

C

D

E

F

Figure 194.—*Octopus*. A. Egg case of *Octopus cyanea*. B, C, D. Color phases of *O. cyanea*. E. *O. cyanea* with web spread (red arms are those of *O. ornatus*). F. *O. ornatus*. (Pictures courtesy of William F. Van Heukelem.)

eyes prominent; funnel small, conical; arms subequal, three or four times the length of the body; umbrella moderately developed, equal all around and forming a contractile web along the outer margin of the arms; suckers large, rather flattened and closely set; third right arm of male not shorter than its mate, hectocotylyzed portion small; integument generally smooth. *Color:* gray.

This is the day squid or *he'e mauli* which lives on reef flats and other rocky substrata to depths of 50 m. Large animals are abundant from July and August through December; small specimens (50 mm) are found in tide pools and other shallow areas from January through May (Van Heukelem, 1966). *He'e* live in shallow holes 30 to 60 cm deep, the entrance to which is marked by small piles of coral rubble and crab shells. The animals forage during the day, feeding principally on crabs and shrimps by jumping on their prey, enveloping them in the interbranchial web, killing them by toxin secreted from the salivary gland, dismembering their victims, and extracting the tissues (Van Heukelem, 1966). Small specimens have caused painful wounds in humans (Weaver, 1964a). Females lay their eggs on a hard substrate, with the eggs hatching at night three to five weeks after laying (Van Heukelem, 1973). There is a pelagic larval stage of perhaps about 30 days, and life span is about 14 months after settlement (Van Heukelem, 1973).

Octopus ornatus Gould, 1852. Fig. 194 F. Length to 650 mm. *Animal:* subglobose, somewhat expanded and rounded posteriorly; mantle opening wide and extending on either side to a point about halfway between the eye aperture and funnel; head rounded, not excavated above or below; eyes fairly prominent with small openings; head and body separated by a decided constriction; funnel long and extending about two-thirds of the distance to the ventral margin of the umbrella; arms long and graceful, the dorsal pair about seven times the length of the head and body, attenuate, the tips nearly filiform; umbrella small, developed most between the dorsal arms; suckers numerous and crowded, somewhat elevated and discoid with fairly deep cups; third right arm in the male shorter than its mate on the opposite side; integument coarse and papillose dorsally, smooth below. *Color:* orange-brown or dark red with white spots.

O. ornatus is the night squid, *he'e pūloa;* like *O. cyanea* it lives in holes on reef flats and other rocky substrata to depths of about 50 m, but it forages after dark.

O. ornatus was described from the Hawaiian Islands.

Class APLACOPHORA

(= SOLENOGASTRES)

The aplacophorans are primitve but highly specialized animals which in many respects are unlike other mollusks. Wormlike and without a shell, these animals are bottom dwellers found for the most part at depths of more than 50 m. They are usually

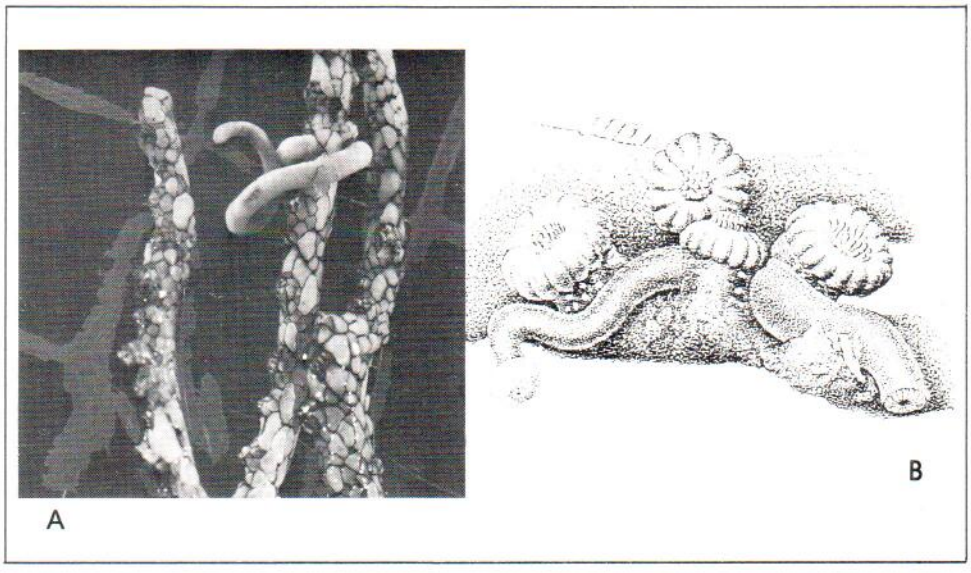


Figure 195.—A. A ventroplicid solenogaster coiled around a gorgonid. B. *Chaetoderma hawaiiensis* (Caudofoveata) (From Heath, 1911).

small (less than 5 cm in length). Their molluscan features include a ladderlike nervous system like that of the chitons and the monoplacophoran genus *Neopilina*, a radula or radular elements, and several features characteristic of the molluscan mantle cavity (Scheltema, 1978). Although they lack a shell, the epidermis is embedded with calcareous spicules.

There are two subclasses, the animals in each distinguished by their different life styles. In the Neomeniomorpha (= Ventroplicida) the worm-shaped animals have a ventral groove with a narrow foot and locomotion is by gliding on a mucus trail. These aplacophorans apparently feed on attached bottom-dwelling animals such as coelenterates and are sometimes found coiled around deep-dwelling gorgonaceans (Fig. 195 A). The usually smaller animals of the subclass Chaetodermomorpha (= Caudofoveata) (Fig. 195 B) have an oral shield and lack a ventral groove. They are burrowers in the soft substrate and apparently feed on detritus.

Six species of aplacophorans were described from the *Albatross* collections from depths of 80 to 500 m (Heath, 1911). Several other species are now known to occur in Hawaiian waters but are thus far undescribed.

LITERATURE CITED

Abe, T.

1964. *Opisthobranchia of Toyama Bay and Adjacent Waters.* Tokyo: Hokuryo-Kan.

Abbott, R. T.

1950. The Molluscan Fauna of the Cocos Keeling Islands, Indian Ocean. *Bull. Raffles Mus. Singapore,* 22:68-98.

1958. The Gastropod Genus *Assiminea* in the Philippines. *Proc. Acad. Natural Sciences, Philadelphia* 110:213-278.

1960. The Genus *Strombus* in the Indo-Pacific. *Indo-Pacific Mollusca* 1(2):33-146.

1961. The Genus *Lambis* in the Indo-Pacific. *Indo-Pacific Mollusca* 1(3):147-174.

1967. *Strombus (Canarium) wilsoni* New Species from the Indo-Pacific. *Indo-Pacific Mollusca* 1(7):455-456.

1968. The Helmet Shells of the World (Cassididae). *Indo-Pacific Mollusca* 2(9):7-201.

1974. *American Seashells.* (2nd ed.) New York: Van Nostrand Reinhold.

Abraham, P. S.

1877. Revision of the Anthobranchiate Nudibranchiate Mollusca, with Descriptions or Notices of Forty-one Hitherto Undescribed Species. *Proc. Zoological Soc. London,* pp. 197-269.

Adam, W., and E. Leloup

1938. Prosobranchia et Opisthobranchia. In Resultats Scientifiques du Voyage aux Indes Orientales Neerlandaises. *Mem. Musée Royal d'Histoire Naturelle de Belgique* 2(19):1-209.

Adams, A.

1850a. Monographs of Cyclostrema, Marryat, and *Separatista,* Gray; Two Genera of Gasteropodous Mollusks. *Proc. Zoological Soc. London,* pp. 41-46.

1850b. Monograph of the Family Bullidae. In G. B. Sowerby, *Thesaurus Conchyliorum* Vol. 2, pp. 553-608. London.

1852a (1851). A Catalogue of the Species of *Emarginula* . . . in the Collection of H. Cuming, Esq. *Proc. Zoological Soc. London,* Pt. 19, pp. 82-92.

1852b (1851). Catalogue of the Species of *Nassa,* a Genus of Gasteropodous Mollusca Belonging to the Family Buccinidae, in the Collection of Hugh Cuming, Esq., with the Description of Some New Species. *Proc. Zoological Soc. London,* Pt. 19, pp. 94-114.

1853a (1851). Descriptions of Fifty-two New Species of the Genus *Mitra,* from the Cumingian Collection. *Proc. Zoological Soc. London,* Pt. 19, pp. 132-141.

1853b. (1851). Descriptions of Several New Species of *Murex, Rissoina, Planaxis, & Eulima,* from the Cumingian Collection. *Proc. Zoological Soc. London,* Pt. 19, pp. 267-272.

1853c. Descriptions of New Shells from the Collection of H. Cuming, Esq. *Proc. Zoological Soc. London,* pp. 69-74.

1854a (1851). Descriptions of New Species of *Eulima, Triphoris,* etc., from the Collection of Hugh Cuming, Esq. *Proc. Zoological Soc. London,* Pt. 19, pp. 276-279.

1854b (1852). Descriptions of a New Genus, and of Several New Species, of Mollusca, from the Cumingian Collection. *Proc. Zoological Soc. London,* Pt. 20, pp. 92-95.

1854c (1853). Descriptions of New Shells from the Collection of H. Cuming, Esq. *Proc. Zoological Soc. London,* Pt. 21, pp. 69-74.

1854d. Monograph of the Genera *Eulima, Niso, Leiostraca, Obeliscus, Pyramidella* and *Monoptygma.* In G. B. Sowerby, *Thesaurus Conchyliorum,* Vol. 2, pp. 793-826. London.

Adams, A. (cont.)
1854e. Descriptions of New Species of *Semele, Rhizochilus, Plotia* and *Tiara* in the Cumingian Collection. *Proc. Zoological Soc. London,* pp. 94-99.
1855a (1854). Monograph of *Acteon* and *Solidula,* Two Genera of Gasteropodous Mollusca, with Descriptions of Several New Species from the Cumingian Collection. *Proc. Zoological Soc. London,* Pt. 22, pp. 58-62.
1855b (1854). Descriptions of Twenty-seven New Species of Shells from the Collection of Hugh Cuming, Esq. *Proc. Zoological Soc. London,* Pt. 22, pp. 311-317.
1855c (1853). A Monograph of *Fossar,* a Genus of Gasteropodous Mollusca. *Proc. Zoological Soc. London,* Pt. 21, pp. 186-187.
1855d (1854). Descriptions of Some New Species of Lophoceridae and Philinidae, from the Cumingian Collection. *Proc. Zoological Soc. London,* pp. 94-95.
1855e (1853). Contributions Towards a Monograph of the Genus *Chemnitzia. Proc. Zoological Soc. London,* Pt. 21, pp. 178-182.
1860a. Mollusca Japonica; New Species of *Aclis, Ebala, Dunkeria,* etc. *Ann. Mag. Natural History* (Ser. 3) 6(32):118-121.
1860b. On some New Genera and Species of Mollusca from Japan. *Ann. Mag. Natural History* (Ser. 3) 6(35):331-337.
1861. On some New Species of Mollusca from the North of China and Japan. *Ann. Mag. Natural History* (Ser. 3) 8(44):135-142.
1862a. On Some New Species of Scissurellidae from the Seas of China and Japan. *Ann. Mag. Natural History* (Ser. 3) 10:346-348.
1862b. On the Animal and Affinities of *Scaliola,* a Genus of Mollusca from Japan. *Ann. Mag. Natural History* (Ser. 3) 10(60):420-421.
1864a. On some New Genera and Species of Mollusks from the Seas of China and Japan. *Ann. Mag. Natural History* (Ser. 3) 13:307-310.
1864b. On the Species of Mitridae Found in the Seas of Japan. *J. Linnaean Soc. London* 7:198-201.
1868. On the Species of Caecidae, etc. *Ann. Mag. Natural History* (Ser. 4) 2:364-365.

Adams, A., and L. Reeve
1848-1850. Mollusca. In A. Adams (ed.), *The Zoology of the Voyage of H.M.S.* Samarang. . . . London: Reeve, Benham and Reeve.

Adams, F. W.
1966. The Habitat of *Strombus hawaiensis* is Found. *Hawaiian Shell News* 14(14):1, 3.
1967. Some notes on *Strombus dentatus. Hawaiian Shell News* 15(11):1, 8.

Adams, H.
1860. On Two New Genera of Acephalous Mollusks. *Proc. Zoological Soc. London,* p. 369.
1868. Descriptions of Some New Species of Shells Collected by Geoffrey Nevill, Esq. at Mauritius, the Isle of Bourbon, and the Seychelles. *Proc. Zoological Soc. London,* pp. 288-292.
1869. Descriptions of a New Genus and Fourteen New Species of Marine Shells. *Proc. Zoological Soc. London,* Pt. 1, pp. 272-275.
1872. Further Descriptions of New Species of Shells, Collected by Robert M'Andrew, Esq. in the Red Sea. *Proc. Zoological Soc. London,* pp. 9-12.

Adams, H., and A. Adams
1853-1858. *The Genera of Recent Mollusca; Arranged According to their Organization.* 3 vols. London: John van Voorst.
1864 (1863). Descriptions of New Species of Shells Chiefly from the Cumingian Collection. *Proc. Zoological Soc. London,* pp. 428-435.

Alder, J.
1844. Descriptions of Some New British Species of *Rissoa* and *Odostomia. Ann. Mag. Natural History* 13:323-328.

Alder, J., and A. Hancock
1866 (1864). Notice on a Collection of Nudibranchiate Mollusca Made in India by Walter Eliot, Esq., with Descriptions of Several New Genera & Species. *Trans. Zoological Soc. London* 5(3):113-147.

Allan, J. K.
1947. Nudibranchia from the Clarence River Heads, north coast, New South Wales. *Rec. Australian Museum* 21(8):432-463.

Allan, J. K. (cont.)

1950. *Australian Shells*. Melbourne: Georgian House.

1956. *Cowry Shells of World Seas*. Melbourne: Georgian House.

Angas, G. F.

1864. Descriptions d'espèces nouvelles appartenant à plusieurs genres de Mollusques nudibranches des environs de Port-Jackson (Nouvelle-Galles des Sud). . . . *J. Conchyliologie* 12:43-70.

1867. Descriptions of Thirty-Two New Species of Marine Shells from the Coast of New South Wales. *Proc. Zoological Soc. London*, pp. 110-117.

1877. Descriptions of One Genus and Twenty-Five Species of Marine Shells from New South Wales. *Proc. Zoological Soc. London*, pp. 171-177.

Anon.

1962a. Deep Water Sand-Dwellers. *Hawaiian Shell News* 10(10):7.

1962b. Hawaii's Largest Bivalve. *Hawaiian Shell News* 10(12):1.

1970. New Geographical Record, *Conus sugillatus* in Hawaii. *Hawaiian Shell News* 18(2):6.

Anton, H. E.

1839. *Verzeichniss der Conchylien welche sich in der Sammlung von Hermann Eduard Anton befinden*. Halle.

Arnold, J. M., C. T. Singley, and L. D. Williams-Arnold

1972. Embryonic Development and Post-hatching Survival of the Sepiolid Squid *Euprymna scolopes* under Laboratory Conditions. *Veliger* 14(4):361-364.

Baba, K.

1930a. Studies on Japanese Nudibranchs. *Venus* 2(1):4-9.

1930b. Studies on Japanese Nudibranchs. *Venus* 2(2):43-50.

1930c. Studies on Japanese Nudibranchs. (3). A. Phyllidiidae. B. Aeolididae. *Venus* 2(3):117-125.

1931. A Noteworthy Gill-less Holohepatic Nudibranch *Okadaia elegans* Baba, with Reference to its Internal Anatomy. *Annot. Zoologica Japonenses* 13:63-88.

1933. Preliminary Note on the Nudibranchia Collected in the Vicinity of the Amakusa Marine Biological Laboraty. *Annot. Zoologica Japonenses* 14(1):165-179.

1936. Opisthobranchiata of the Ryukyu (Okinawa) Islands. *J. Dept. Agriculture, Kyushu Imperial Univ.* 5:1-50.

1937. Contribution to the Knowledge of a Nudibranch, *Okadaia elegans* Baba. *Japanese J. Zoology* 7:147-190.

1949. *Opisthobranchia of Sagami Bay*. Tokyo: Iwanami Shoten.

1953. Three New Species and Two New Records of the Genus *Glossodoris* from Japan. *Publ. Seto Marine Biological Laboratory* 3(2):205-211.

1955. *Opisthobranchia of Sagami Bay: Supplement*. Tokyo: Iwanami Shoten.

1957. The Species of the Genus *Elysia* from Japan. *Publ. Seto Marine Biological Laboratory* 6(1):69-74.

1965. The Anatomy of *Facelinella quadrilineata* (Baba). (Nudibranchia-Eolidioidea). *Publ. Seto Marine Biological Laboratory* 11:109-115.

1969. Records of *Learchis indica* Bergh, 1896 from Japan and Hawaii (Nudibranchia-Eolidoidea). *Publ. Seto Marine Biological Laboratory* 16(6):400-403.

1974. Some Comments on *Lobiger souverbiei* Fischer, 1856, Reidentified, of Japan (Opisthobranchia: Sacoglossa: Lobigeridae). *Veliger* 16(3):253-257.

Baker, F., and V. D. P. Spicer

1935. New Species of Mollusks of the Genus *Triphora*. *Trans. San Diego Soc. Natural History* 8(7):35-46.

Baldwin, D. D.

1887. Land Shells of the Hawaiian Islands. *Hawaiian Almanac and Annual*, pp. 1-9.

1893. *Catalogue of Land and Fresh Water Shells of the Hawaiian Islands*. Honolulu: Press Publishing Co.

1895. Descriptions of New Species of Achatinellidae from the Hawaiian Islands. *Proc. Acad. Natural Sciences Philadelphia*, pp. 214-236.

1898. Hawaiian Cypraeidae. *Nautilus* 11(11):123.

Barde, C. de

1814. *A Descriptive Catalogue of the Different Subjects Represented in the Large Water Colour Drawings by the Chevalier de Barde; now exhibiting at Mr. Bullock's Museum, etc.* London.

Barnard, K. H.
1927. South African Nudibranch Mollusca, with Descriptions of New Species, and a Note of Some Specimens from Tristan d'Acunha. *Ann. South African Mus.* 25:171-215.
1963. Contributions to the Knowledge of South African Marine Mollusca. Part III. Gastropoda: Prosobranchia: Taenioglossa. *Ann. South African Mus.* 47(1):1-199.
1964. Contributions to the Knowledge of South African Marine Mollusca. Part V. Lamellibranchiata. *Ann. South African Mus.* 47(3):361-593.

Bartsch, P.
1911. The West American Mollusks of the Genus *Nodulus*. *Proc. U.S. National Mus.* 41:289-291.
1913. The Philippine Mollusks of the Genus *Dimya*. In Scientific Results of the Philippine Cruise of the Fisheries Steamer Albatross, 1907-1910, No. 27. *Proc. U.S. National Mus.* 45:305-307.
1921. A New Classification of the Shipworms and Descriptions of Some New Wood Boring Mollusks. *Proc. Biological Soc. Washington* 34:25-32.
1923. Additions to our Knowledge of Shipworms. *Proc. Biological Soc. Washington* 36:95-102.
1931. A New Pearl Oyster from the Hawaiian Islands. *Proc. U.S. National Mus.* 79:1-2.

Bartsch, P., and H. A. Rehder
1943. New Cones from the Hawaiian Islands. *Proc. Biological Soc. Washington* 56:85-88.

Basedow, H., and C. Hedley
1905. South Australian Nudibranchs, and an Enumeration of the Known Australian Species. *Trans. Royal Soc. South Australia* 29:134-160.

Bayer, C.
1933. Catalogue of the Cymatiidae in the Rijks Museum van Natuurlijke Historie. *Zoologische Meded., Leiden* 16:33-59.

Bayer, F. M., and G. N. Neurohr
1946. Life on a Tropical Pacific Reef. *Mollusca* 1:107-112.

Bebbington, A., and G. H. Brown
1975. *Aplysia parvula* Guilding in Mörch, an Opisthobranch New to the British Fauna. *J. Conchology* 28:329-333.

Beck, J. D.
1962. Shelling on Island of Hawaii. *Hawaiian Shell News* 11(1):7.

Bennett, F. D.
1840. *Narrative of a Whaling Voyage Round the Globe. . . .*, 2 vols. London.

Berg, C. J., Jr.
1971a. The Egg Capsule and Early Veliger of *Charonia tritonis* (Linnaeus). *Veliger* 13:298-299.
1971b. A Comparative and Ontogenetic Study of the Behavior of Strombid Gastropods. Ph.D. Dissertation, Univ. Hawaii, Honolulu, Hawaii.
1972. Ontogeny of the Behavior of *Strombus maculatus* (Gastropoda: Strombidae). *American Zoologist* 12:427-443.

Bergh, L. S. R.
1870a-1892a. Malacologische Untersuchungen. Nudibranchien. In C. G. Semper, *Reisen im Archipel der Philippinen*, Vol. 2, Pt. 1-4. Leipzig.
1884b. Report on the Nudibranchiata dredged by H. M. S. Challenger. . . . *Report Scientific Results Voyage of H. M. S.* Challenger, *Zoology*. Vol. 10.
1889b. Bidrag til en monografi af phyllidierne. *Naturh. Tidsskr.* 5:358-542.
1896. Eolidiens d'Amboine. *Revue Suisse Zoologie* 4:385-394.
1900. Ergebnisse einer reise nache dem Pacific (Schauinsland 1896-1897). Die Opisthobranchier. *Zoologische Jahrbücher* 13:207-246.
1905. Die Opisthobranchiata der Siboga-Expedition. *Siboga-Expeditie* 50:1-248.

Bernardi, A-C.
1861. Description d'especes nouvelles. *J. Conchyliologie* 9:46-49.

Bernstein, A. S.
1970. Notes on the Ecology of *Drupa morum*, 1798 in Hawaii. Abstr. in *The Biology of Molluscs*, Univ. Hawaii, Hawaii Inst. Marine Biology, Tech. Rep. 18:4.

Berry, S. S.
1909. Diagnoses of New Cephalopods from the Hawaiian Islands. *Proc United States National Mus.* 37:407-419.
1913. Some New Hawaiian Cephalopods. *Proc. United States National Mus.* 45:563-566.

Berry, S. S. (cont.)
1914. The Cephalopoda of the Hawaiian Islands. *Bull. Bur. Fisheries, Washington* 32:255-362.

Bertsch, H.
1970. *Dolabrifera dolabrifera* (Rang, 1828): Range Extension to the Eastern Pacific. *Veliger* 13(1):110.

Beu, A. G.
1970a. The Mollusca of the Genus *Charonia* (Family Cymatiidae). *Trans. Royal Soc., New Zealand Biological Science* 11(16):205-223.
1970b. The Mollusca of the Subgenus *Monoplex* (Family Cymatiidae). *Trans. Royal Soc., New Zealand Biological Science* 11(17):225-237.
1971. New Light on the Variation and Taxonomy of the Bivalve *Hiatella*. *New Zealand J. Geology and Geophysics* 14(1):64-66.
1976. New Records of Cymatiidae (Gastropoda: Prosobranchia) from Kapitean to Castle Cliffian (Late Miocene to Early Pleistocene) Rocks of East Cape District, New Zealand. *New Zealand J. Geology and Geophysics* 29(2):297-310.

Beu, A. G., and F. M. Climo
1974. Mollusca from a Recent Coral Community in Palliser Bay, Cook Strait. *New Zealand J. Marine and Freshwater Res.* 8(2):307-332.

Bilyard, G. R.
1974. The Feeding Habits and Ecology of *Dentalium entale stimpsoni* Henderson (Mollusca: Scaphopoda). *Veliger* 17(2):126-138.

Blainville, H. M., D. de
1832. Disposition méthodique des espèces récentes et fossiles des genres *Pourpre, Ricinule, Licorne,* et *Concholépas* de M. de Lamarck et description des espèces nouvelles ou peu connues, faisant partie de la collection du Muséum d'Histoire Naturelle de Paris. *Nouv. Ann. Musée d'Histoire Naturelle, Paris* 1:189-263.

Bloxam, A.
1826. Appendix. Of the Natural History of the Sandwich Islands. In G. A. Byron, *Voyage of H.M.S.* Blonde *to the Sandwich Islands in the Years 1824-25*. London: Murray.
1925. *Diary of Andrew Bloxam Naturalist of the "Blonde."* B. P. Bishop Museum Spec. Publ. 10. Honolulu.

Blumenstock, D. I., and S. Price
1972. Climates of the States: Hawaii. In E. A. Kay (ed.), *A Natural History of the Hawaiian Islands. Selected Readings*. Honolulu: Univ. Press Hawaii.

Boettger, O.
1907. Die Odostomien (Moll.) des mitteloligocaenen Meeresandes von Waldboeckelheim bei Kreuznach. *Nachrichtsbl. Deutches Malacozoologie Gesellsch.*, pp. 77-82.

Born, I. von
1778. *Index Rerum Naturalium Musei Caesarei Vindobonensis*. Part I: *Testacea*. Vienna.
1780. *Testacea musei Caesarei Vindobonensis*. Vienna.

Bosch, H. F.
1965. A Gastropod Parasite of Solitary Corals in Hawaii. *Pacific Science* 19(2):267-268.

Boss, K. J.
1965a. Convergence of an Acentric Sculptural Trait in the Tellinacea. *American Malacological Union Bull.* 32:5.
1965b. Symbiotic Erycinacean Bivalves. *Malacologia* 3(2):183-195.
1969. The Subfamily Tellininae in South African Waters (Bivalvia, Mollusca). *Bull. Mus. Comparative Zoology, Harvard* 138(4):81-162.

Boss, K. J., and D. R. Moore
1967. Notes on *Malleus (Parimalleus) candeanus* (d'Orbigny) (Mollusca: Bivalvia). *Bull. Marine Science* 17:85-94.

Bratcher, T.
1977. Deshayes' Terebrid Types in École des Mines, Paris. *Nautilus* 91:39-42.

Brazier, J.
1877. Mollusca of the Chevert Expedition. *Proc. Linnaean Soc. New South Wales* 1:288-301; 362-388.

Brick, R. W.
1970. *Some Aspects of Raft Culture of Oysters in Hawaii*. Hawaii Inst. Marine Biology Tech. Rep. No. 24, 47 pp.

Briggs, J. C.
1966. Oceanic Islands, Endemism, and Marine Paleotemperatures. *Systematic Zoology* 15(2):153-163.
1974. *Marine Zoogeography*. New York: McGraw Hill.

Brock, V. E.
1960. The Introduction of Aquatic Animals into Hawaiian Waters. *Int. Revue ges. Hydrobiologie* 45:463-480.

Brock, V. E., and T. C. Chamberlain
1968. A Geological and Ecological Reconnaissance off Western Oahu, Hawaii, Principally by Means of the Research Submarine "Asherah." *Pacific Science* 22(3):373-394.

Broderip, W. J.
1832. Characters of New Species of Mollusca and Conchifera, Collected by Mr. Cuming. *Proc. Zoological Soc. London*, Pt. 2, pp. 4-8.
1833 (1832). Characters of New Species of Mollusca and Conchifera, Collected by Mr. Cuming. *Proc. Zoological Soc. London*, Pt. 2, pp. 194-202.
1836 (1835). Characters of New Genera and Species of Mollusca and Conchifera, Collected by Mr. Cuming. *Proc. Zoological Soc. London*, Pt. 3, pp. 192-197.

Broderip, W. J., and G. B. Sowerby
1829. Observations on New and Interesting Mollusca Contained, for the Most Part, in the Museum of the Zoological Society. *Zoological J., London* 4:359-379.

Bromley, J.
1963. A Mollusk Parasite on Sea Urchins. *Hawaiian Shell News* 11(9):2.

Broughton, W. R.
1804. *A Voyage of Discovery to the North Pacific Ocean . . . in His Majesty's Sloop Providence . . . 1795, 1796, 1797, 1798. . . .* London.

Bruguière, J. G.
1789-1816. *Encyclopédie méthodique ou par ordre de mateières*. Histoire naturelle des Vers, des Mollusques. . . . 1:1-344; 345-758, 1792; Atlas, pl. 1-189, 1791; 190-286, 1797; 287-390, 1798; 391-488, 1816 (carried on by Deshayes).

Bryan, W. A.
1915. *Natural History of Hawaii*. Honolulu: The Hawaiian Gazette.
1919. A Hawaiian Form of *Tapes phillippinarum*. *Nautilus* 32(4):124-125.

Burch, R. D.
1962. A Range Extension for Two Species of Hawaiian Terebridae (Gastropoda). *Veliger* 5(1):55-56.
1965. New Terebrid Species from the Indo-Pacific Ocean and from the Gulf of Mexico, with New Locality Records and Provisional Lists of Species Collected in Western Australia and at Sabah, Malaysia (Mollusca: Gastropoda). *Veliger* 7(4):241-253.

Burgess, C. M.
1963. Pele Log. *Hawaiian Shell News* 11(10):1.
1964. M. V. "Pele" Dredges Puzzling Species. *Hawaiian Shell News* 12(4):1.
1967. A New Hawaiian Cypraea. *Nautilus* 81(1):6-11.
1975. The "Carneola Complex." Some Further Thoughts on Three (or Maybe Four) Related Cowries. *Hawaiian Shell News* 23(7):1, 5.

Burghardt, G. E.
1973. A New Hawaiian Chiton, *Rhyssoplax linsleyi* (Mollusca: Amphineura: Chitonidae). *Proc. California Acad. Science* (4th Ser.) 39(21):501-506.

Burn, R.
1959. Comments on the Australian Umbraculacean Mollusca. *J. Malacological Soc. Australia* No. 3, pp. 28-29.
1965. A Centennial Commentary and Zoogeographical Remarks on Angas' Sydney Nudibranchs (Mollusca, Gastropoda). *J. Conchyliologie* 104:85-93.

Burn, R., and K. R. Natarajan
1970. Taxonomic Notes on *Eolis militaris* Alder and Hancock, 1864 (Opisthobranchia, Eolidacea). *J. Malacological Soc. Australia* 2(1):83-86.

Calabrese, A. R., Jr.
1971. Feeding Observations of *Conus nussatella* (Linnaeus, 1758). *Hawaiian Shell News* 19(1):1.

Campbell, A.
1822. *A Voyage Round the World, from 1806 to 1812 . . .* (3rd ed.) Facsimile reproduction, Honolulu, Hawaii 1967. 220 pp.

Cannon, L. R. G.
1975. On the Reproductive Biology of *Cerithium moniliferum* Kiener (Gastropoda, Cerithiidae) at Heron Island, Great Barrier Reef. *Pacific Science* 29(4):353-359.

Carlson, C., and P. J. Hoff
1973. Some Unshelled Shells of Guam. *Guam Reporter* 3(2):5-8.

Carpenter, P. P.
1857. Report on the Present State of Our Knowledge with Regard to the Mollusca of the West Coast of North America. *Rep. 26th Meeting British Assoc. Adv. Science,* 1856, pp. 159-368.
1864. Supplementary Report on the Present State of Our Knowledge with Regard to the Mollusca of the West Coast of North America. *Rep. British Assoc. Adv. Science,* 1863, pp. 517-686.

Carriker, M. R., and L. G. Williams
1978. The Chemical Mechanism of Shell Dissolution by Predatory Boring Gastropods: A Review and an Hypothesis. *Malacologia* 17(1):143-156.

Cass, P. H.
1967. Some Aspects of the Biology of the Gastropod Mollusc Genus *Hipponix* on Oahu, Hawaii. Master of Science Thesis, Univ. Hawaii, Honolulu, Hawaii.

Cate, C. N.
1960. A New Hawaiian Subspecies of *Cypraea cernica* Sowerby. *Veliger* 3(1):3-7.
1961. Redescription of *Cypraea tigris lyncichroa* Melvill, 1888. *Veliger* 3(3):66-69.
1962. *Cypraea chinensis* Gmelin, 1791, in Hawaii. *Veliger* 5(2):74-77.
1965. Hawaiian Cowries. *Veliger* 8(2):45-61.
1967. The Cowries of the Ryukyu Islands. *Veliger* 10(1):13-41.
1969. Two New Species of the Genus *Volva* Röding, 1798 (Ovulidae Fleming, 1828). *Veliger* 11(4):364-366.
1973. A Systematic Revision of the Recent Cypraeid Family Ovulidae (Mollusca: Gastropoda). *Veliger* 15, Supplement, 116 pp.

Cate, J.
1960. Range Extension and Synonymy for *Mitra nigra* (Schröter, 1788). *Veliger* 3(2):49-50.
1962a. On the Identification of Five Pacific *Mitra*. *Veliger* 4(3):132-134.
1962b. Revision of Some Hawaiian Mitrid Species. *Veliger* 4(3):140-149.
1962c. A New Species of *Mitra* (Gastropoda) from Hawaii. *Veliger* 5(2):80-83.
1963. Revision of Dall's Hawaiian Mitrids with Descriptions of Three New Species. *Veliger* 6(1):23-43.

Cate, J. M., and R. D. Burch
1964. Mitridae and Terebridae (Mollusca, Gastropoda) of Malaita, Fiji and Bileau Island, New Guinea. *Veliger* 6(3):139-147.

Cernohorsky, W. O.
1964a. The Cypraeidae of Fiji (Mollusca: Gastropoda). *Veliger* 6(4):177-201.
1964b. The Conidae of Fiji (Mollusca: Gastropoda). *Veliger* 7(2):61-94.
1965. The Mitridae of Fiji. *Veliger* 8(2):70-160.
1967a. The Bursidae, Cymatiidae, and Colubrariidae of Fiji. *Veliger* 9(3):310-329.
1967b. *Marine Shells of the Pacific*. Sydney: Pacific Publications, 248 pp.
1969. The Muricidae of Fiji, Part II — Subfamily Thaidinae. *Veliger* 11(4):293-315.
1970a. New Mitridae and Volutomitridae. *Nautilus* 83(3):95-104.
1970b. *Systematics of the Families Mitridae and Volutomitridae (Mollusca: Gastropoda)*. Bull. Auckland Inst. Mus., 190 pp.
1971a. Indo-Pacific Pisaniinae (Mollusca: Gastropoda) and Related Buccinid Genera. *Rec. Auckland Inst. Mus.* 8:137-167.

Cernohorsky, W. O. (cont.)
1971b. The Family Naticidae (Mollusca: Gastropoda) in the Fiji Islands. *Rec. Auckland Inst. Mus.* 8:169-208.
1972a. *Marine Shells of the Pacific,* Vol. II. Sydney: Pacific Publications, 411 pp.
1972b. Indo-Pacific Nassariidae (Mollusca: Gastropoda). *Rec. Auckland Inst. Mus.* 9:125-194.
1974. Remarks on the Taxonomy of Japanese Nassariidae. *Venus* 33(2):57-64.
1975a. Supplementary Notes on the Taxonomy of Buccinid Species of the Subfamily Pisaniinae (Mollusca: Gastropoda). *Rec. Auckland Inst. Mus.* 12:175-211.
1975b. The Taxonomy of Some Indo-Pacific Mollusca. Part 3. With Descriptions of New Taxa and Remarks on an Ecuadorian Fossil Species of Turridae. *Rec. Auckland Inst. Mus.* 12:213-214.
1976a. The Mitridae of the World. Pt. 1. The Subfamily Mitrinae. *Indo-Pacific Mollusca* 3(17):273-528.
1976b. The Taxonomy of Some Indo-Pacific Mollusca. Pt. 4. With Descriptions of New Taxa and Remarks on *Nassarius coppingeri* (Smith). *Rec. Auckland Inst. Mus.* 13:11-129.
1977a. Note on Two Pacific Gastropods. *Auckland Mus. Conchological Bull.* Ser. 2.
1977b. The Taxonomy of Some Indo-Pacific Mollusca. Pt. 5. With Descriptions of New Taxa and Remarks on *Nassarius albus* (Say). *Rec. Auckland Inst. Mus.* 14:121-132.
1978a. New Species of Mitridae, Costellariidae and Turridae from the Hawaiian Islands with Notes on *Mitra sphoni* in the Galapagos Islands. *Nautilus* 92:61-67.
1978b. Hawaiian *Nassarius. Hawaiian Shell News* 26(1):4.
1978c. In O. Schoenberg, Range Extension for *Phalium angasi bulla. Hawaiian Shell News* 26(10):12.

Cernohorsky, W. O., and A. Jennings
1966. The Terebridae of Fiji. *Veliger* 9(1):37-67.

Chamisso, A.
1829. Description de deux nouvelles especies de coquilles terrestres des iles Sandwich. *Nova Acta Naturae Curiorsurum* 14:639.

Chavan, A.
1969. Leptonacea, Cyamiacea. *Treatise on Invertebrate Paleontology* Pt. N(2), pp. 518-543.

Chemnitz, J. H.
1780-1795. *Neues systematisches Conchylien-Cabinet:* Pts. 4-11. Nürnberg.

Chenu, J. C.
1842-1853. *Illustrations conchyliologiques ou description et figures de toutes les coquilles connues, vivantes et fossiles.* Vols. 1-4. Paris.

Choris, L.
1822. *Voyage pittoresque autour du monde, avec des portraits de sauvages d'Amerique, d'Asie, d'Afrique. . . .* Paris: Didot.

Clapp, W. F.
1923. A New Species of *Teredo* from Florida. *Proc. Boston Soc. Natural History* 37(2):31-38.

Clarke, A. H., Jr.
1960. Catalogue and Illustrations of Mollusks Described by Wesley Newcomb, with a Biographical Resume. *Bull. American Paleontology* 41(188):135-157.

Clench, W. J., and R. D. Turner
1957. The Family Cymatiidae in the Western Atlantic. *Johnsonia* 3(36):189-244.

Climo, F. M.
1975. The Anatomy of *Gegania valkyrei* Powell (Mollusca: Heterogastropoda: Mathildidae) with Notes on Other Heterogastropods. *J. Royal Soc. New Zealand* 5(3):275-288.

Cobb, J. N.
1902. Commercial Fisheries of the Hawaiian Islands. In: W. S. Jordan and D. Evermann, *The Fishes and Fisheries of the Hawaiian Islands: A Preliminary Report.* Washington: U. S. Government Printing Office.
1903. The Aquatic Resources of the Hawaiian Islands, Sec. III. The Commercial Fisheries. *Bull. United States Fish Comm.* 23, Pt. 2. Washington.

Coleman, R. A.
1923. Efforts to Acclimatize Atlantic Oyster and Soft Clam in the Hawaiian Islands. *Nautilus* 36:138-139.

Collingwood, C.
1881. On Some New Species of Nudibranchiate Mollusca from the Eastern Seas. *Trans. Linnaean Soc. London, Zoology* 2(2):123-140.

Conrad, T. A.
1837. Descriptions of New Marine Shells from Upper California, Collected by Thomas Nuttall, Esq. *J. Acad. Natural Sciences Philadelphia* 7(2):227-268.

Cook, J., and J. King
1784. *A Voyage to the Pacific Ocean, Undertaken by Command of His Majesty . . . Performed Under the Direction of Captains Cook, Clerke and Gore, in His Majesty's Ships, "Resolution" and "Discovery," in the Years 1767, 1777, 1778, 1779 and 1780.* 3 vols. London: Nicol and Cadell.

Cook, S. B.
1969. Experiments on Homing in the Limpet *Siphonaria normalis*. *Animal Behavior* 17:679-682.

Cooke, A. H.
1895. Molluscs. In, A. H. Cooke, A. E. Shipley, and F. R. C. Reed, *Molluscs, Brachiopods (Recent), Brachiopods (Fossils)*. London: Macmillan and Co.
1919. The Radula in *Thais, Drupa, Morula, Concholepas, Cronia, Iopas*, and the Allied Genera. *Proc. Malacological Soc. London* 13(3&4):90-110.

Corgan, James X.
1972. Pacific Species of *Nesiodostomia* Pilsbry, 1918, and *Puposyrnola* Cossmann, 1921 (Gastropoda: Pyramidellacea). *Veliger* 14(4):355-360.

Corn, M. L.
1973. A Rare Hawaiian Miter. *Hawaiian Shell News* 21(11):1.

Corney, P.
1896. *Voyages in the Northern Pacific. Narrative of Several Trading Voyages from 1813 to 1818, Between the Northwest Coast of America, the Hawaiian Islands and China. . . .* Honolulu: T. G. Thrum.

Correa, L. H.
1969. A Comparative Study of the Osmo-Regulatory Capacities of *Cellana exaratus* and *C. sandwichensis*. Master of Science Thesis, Univ. Hawaii, Honolulu, Hawaii.

Costa, E. M. da
1776. *Elements of Conchology: Or An Introduction to the Knowledge of Shells*. London.

Couthouy, J. P.
1844. Remarks Upon Coral Formations in the Pacific, with Suggestions as to the Causes of their Absence in the Same Parallels of Latitude on the Coast of South America. Conclusion. *Polynesian* June 22, p. 17.

Cowan, I. McT.
1974. The West American Hipponicidae and the Application of *Malluvium, Antisabia*, and *Hipponix* as Generic Names. *Veliger* 16(4):377-380.

Cross, E.
1963. Hawaiian Race of *Murex torrefactus*. *Hawaiian Shell News* 12(1):1.
1965. Shelling Areas on Oahu. Part VI. *Hawaiian Shell News* 13(6):5-6.
1967a. Live *Murex elongatus* Solander Collected. *Hawaiian Shell News* 15(1):1.
1967b. *Conus spiceri* and Other "Look Alike" Cone Shells. *Hawaiian Shell News* 15(2):5.
1967c. A Living *Cymatium clandestium* [sic]. *Hawaiian Shell News* 15(4):1.
1967d. Meet *Mitra papalis* (Linnaeus). *Hawaiian Shell News* 15(4):7.
1973. Hawaiian Deep Water Miters. *Hawaiian Shell News* 21(6):1.

Crosse, H.
1858. Observations sur le genre Cône et description de trois espèces nouvelles, avec un catalogue alphabétique des Cônes actuellement connus. *Revue Magasine Zoologie Pure Appl.* (Ser. 2) 10:113-127.
1870a. Diagnoses Molluscorum Novorum. *J. Conchyliologie* 18:301-304.
1870b. Diagnoses Molluscorum Novae Caledoniae Incolarum. *J. Conchyliologie* 18:238-248.
1871. Description d'espèces inédites provenant de la Nouvelle Calédonie. *J. Conchyliologie* 19:193-201.

Crossland, C.
1905. The Oecology and Deposits of the Cape Verde Marine Fauna. *Proc. Zoological Soc. London* 170:170-186.

Cuvier, G. L. C. F. D. Baron
1804a. Mémoire sur le genre *Doris*. *Ann. Mus. National Histoire Naturelle, Paris* 4:447-473.
1804b. Mémoire sur la Phyllididie et sur le Pleurobranche, deux nouveaux genres de mollusques. . . . *Ann. Mus. National Histoire Naturelle* 5:266-276, Pt. 18.
1817. *Le Regne Animal*. Paris: Chez Deterville Libraire. Vol. 2.
1830. Les nudibranches (3). *Le Regne Animal*. Nouvelle ed. 2. Vol. 3.

Dall, W. H.
1871. On the Limpets; with Special Reference to the Species of the West Coast of the Americas, and to a More Natural Classification of the Group. *American J. Conchology* 6(3):227-282.
1881. Reports on the Results of Dredging, under the Supervision of Alexander Agassiz in the Gulf of Mexico, and in the Caribbean Sea, 1877-79, by the U. S. Coast Survey Steamer "Blake". . . . XV. Preliminary Report on the Mollusca. *Bull. Mus. Comparative Zoology, Harvard* 9(2):33-144.
1893. The Phylogeny of the Docoglossa. *Proc. Acad. Natural Science, Philadelphia*, pp. 285-287.
1895. Scientific Results of Explorations by the U. S. Fish Commission Steamer "Albatross." XXXIV. Report on Mollusca and Brachiopoda Dredged in Deep Water, Chiefly Near the Hawaiian Islands, with Illustrations of Hitherto Unfigured Species from Northwest America. *Proc. U. S. National Mus.* 17(1032):675-733.
1900a. [Report to Dr. William T. Brigham on Garrett Collection of Shells.] *B. P. Bishop Mus. Occ. Pap.* 1(2):10-13.
1900b. Notes on the Tertiary Geology of Oahu. *Bull. Geological Soc. America* 11:57-60.
1901. The Structure of Diamond Head, Oahu. *American Geology* 27:386-387.
1903. Hawaiian Phytidae. *Nautilus* 16(9):106.
1904. On the Geology of the Hawaiian Islands. *American J. Science and Arts* (4th Ser.) 17(98):177.
1911. Nature of Tertiary and Modern Marine Faunal Barriers and Currents. *Bull. Geological Soc. America* 22:218-220.
1913. Diagnoses of New Shells from the Pacific Ocean. *Proc. U. S. National Mus.* 45(2002):587-597.
1918. Changes in and Additions to Molluscan Nomenclature. *Proc. Biological Soc. Washington* 31:137-138.
1919. Descriptions of New Species of Mollusks of the Family Turritidae from the West Coast of America and Adjacent Regions. *Proc. U. S. National Mus.* 56:1-86.
1921. Nomenclatorial Notes. *Nautilus* 35(2):49-50.
1923. Notes on *Drupa* and *Morula*. *Proc. Acad. Natural Sciences Philadelphia* 75:303-306.
1924. Notes on Molluscan Nomenclature. *Proc. Biological Soc. Washington* 37:303-306.

Dall, W. H., and P. Bartsch
1906. Notes on Japanese, Indo-Pacific, and American Pyramidellidae. *Proc. U. S. National Mus.* 30(1425):321-369.

Dall, W. H., P. Bartsch, and H. A. Rehder
1938. *A Manual of the Recent and Fossil Marine Pelecypod Mollusks of the Hawaiian Islands*. B. P. Bishop Mus. Bull. 153.

D'Attilio, A.
1964. Some Observations on *Homolocantha anatomica* and *Homolocantha pele*. *Hawaiian Shell News* 12(11):2.

Dautzenberg, P., and J. L. Bouge
1933. Les mollusques testacés marins des établissements Francais de l'Océanie. *J. Conchyliologie* 77(2):41-108; 145-326; 351-469.

Dautzenberg, P., and P. Fischer
1906. Contribution a la faune malacologique de l'Indo-chine. *J. Conchyliologie* 54(3):145-226.

Davis, L. V.
1967. The Suppression of Autonomy in *Linckia multifora* (Lamarck) by a Parasitic Gastropod, *Stylifer linckiae* Sarasin. *Veliger* 9:343-346.

Dell, R. K.
1956. The Archibenthal Mollusca of New Zealand. *Dominion Mus. Bull.* 18:235.
1964. Antarctic and Subantarctic Mollusca: Amphineura, Scaphopoda and Bivalvia. *Discovery Rep.* 33:93-250.

Delle, Chiaje S.
1841. *Descrizione e anotomia degli animali invertebrati della Sicilia citeriore osservati vivi negli anni 1822-1830.* Napoli.

Demond, J.
1957. Micronesian Reef-associated Gastropods. *Pacific Science* 11(3):275-341.

Deshayes, G. P.
1830-1832. *Encyclopédie Méthodique. Histoire naturelle de vers.* Vol. 2, pp. 1-144 (1830), 145-594 (1832). Paris.
1832. [*Pileopsis pilosus*]. *Mag. Zoologie* 2.
1834. In E. J. de La Borde and M. Linant, *Voyage de L'Arabie Petrée.* Paris.
1835-1845. *Histoire naturelle des animaux sans vertèbres.* (2nd ed.) 11 vols. Paris.
1854-1855. New Shells from the Collection of Hugh Cuming, Esq. *Proc. Zoological Soc. London* Pt. 22, pp. 282-368.
1857. Description de'especès novelles du genre *Terebra. J. Conchyliologie* 6:65-102.
1859. A General Review of the Genus *Terebra,* and a Description of New Species. *Proc. Zoological Soc. London,* pp. 270-321.
1863. *Catalogue des Mollusques de L'Île de la Réunion (Bourbon).* Paris.

Dillwyn, L. W.
1817. *A Descriptive Catalogue of Recent Shells, Arranged According to the Linnaean Method; with Particular Attention to the Synonymy.* 2 vols. London.

Dixon, G.
1789. *A Voyage Around the World, . . . 1785-1788. . . .* (2nd ed.) London: G. Golding.

Dohrn, H.
1860. Descriptions of New Species of *Mitra* from the Collection of Hugh Cuming, Esq. *Proc. Zoological Soc. London,* pp. 366-368.
1861. Descriptions of New Shells from the Collection of H. Cuming, Esq. *Proc. Zoological Soc. London,* pp. 205-207.
1862. Descriptions of New Shells. *Proc. Zoological Soc. London,* pp. 202-203.

Duch, T.
1969. Spawning and Development in the Trochid Gastropod *Euchelus gemmatus* (Gould, 1841) in the Hawaiian Islands. *Veliger* 11(4):415-427.

Duclos, P. L.
1832. Description de quelques espèces de pourpres servant de type à six sections établies dans ce genre. *Ann. Science Naturelle Paris* 26:103-112.
1840 (1835). *Histoire naturelle . . . de tous les genres de coquilles univalves marines à l'état vivant et fossile, publiée par monographies. Genre Olive. (Genre Colombelle-Strombe).* Paris.

Dunker, W.
1852a. Diagnoses Molluscorum novorum. *Z. Malakozoologie* 9:49-62.
1852b. Aviculacea nova. *Z. Malakozoologie* 9:73-80.
1858-1870. *Novitates Conchologicae. Mollusca marina. Beschreibung und Abbildung neuer oder aening gekannter Meeres Conchylien.* Cassel.
1860 (1859). Neue japanische Mollusken. *Malakozoologische Blätter* 6:221-240.
1861. Beschreibung neuer Mollusken. *Malakozoologische Blätter* 7:35-45.
1862. Beschreibung neuer Mollusken. *Malakozoologische Blätter* 8:35-45.
1882. *Molluscorum Maris Japonica.* Kassel: Theo Fisher.

Dunlap, M. S.
1975. Symbiosis Between Algal Chloroplasts and the Mollusc *Plakobranchus ocellatus* van Hasselt (Sacoglossa: Opisthobranchia). Ph.D. Dissertation, Univ. Hawaii, Honolulu, Hawaii.

Eales, N. B.
1960. Revision of the World Species of *Aplysia* (Gastropoda, Opisthobranchia). *British Mus. (Natural History) Bull. Zoology* 5:267-400.

Eales, N. B. (cont.)
1970. On the Migration of Tectibranch Molluscs from the Red Sea to the Eastern Mediterranean. *Proc. Malacological Soc. London* 39:217-220.

Edmondson, C. H.
1933. *Reef and Shore Fauna of Hawaii*. B. P. Bishop Mus. Spec. Publ. 22. Honolulu.
1942. Teredinidae of Hawaii. *B. P. Bishop Mus. Occ. Pap.* 17(10):97-150.
1944a. Vertical Distribution of Shipworms in Hawaiian Waters. *Nautilus* 58(2):55-56.
1944b. Incidence of Fouling in Pearl Harbor. *B. P. Bishop Mus. Occ. Pap.* 18(1):1-34.
1946a. *Reef and Shore Fauna of Hawaii*. B. P. Bishop Mus. Spec. Publ. 22. (2nd ed.) Honolulu.
1946b. Dispersal of Shipworms among Central Pacific Islands with Descriptions of New Species. *B. P. Bishop Mus. Occ. Pap.* 18(15):211-224.
1962. Teredinidae, Ocean Travellers. *B. P. Bishop Mus. Occ. Pap.* 23(3):45-59.

Edmondson, C. H., and W. M. Ingram
1939. Fouling Organisms in Hawaii. *B. P. Bishop Mus. Occ. Pap.* 14(14):251-300.

Edmondson, C. H., and I. H. Wilson
1940. The Shellfish Resources of Hawaii. *Proc. 6th Pacific Science Congress* (1939) 3:241-243.

Edmunds, M.
1966. Protective Mechanisms in the Eolidacea (Mollusca Nudibranchia). *Zoological J. Linnaean Soc.* 47(308):27-71.
1971. Opisthobranchiate Mollusca from Tanzania. III. (Suborder: Doridacea). *Zoological J. Linnaean Soc.* 50:339-396.
1972. Opisthobranchiate Mollusca from the Seychelles, Tanzania, and the Congo, now in the Tervuren Museum. *Rev. Zoologie et de Botanique Africaines* 85(1-2):67-92.

Edmunds, M., and T. E. Thompson
1972. Opisthobranchiate Mollusca from Tanzania. IV. Pleurobranchomorpha, Dendronotoidea and Arminoidea. *Proc. Malacological Soc. London* 40:219-233.

Edwards, F. E.
1856. *A Monograph of the Eocene Mollusca, or Descriptions of Shells from the Older Tertiaries of England*. Paleontological Society of England Monogr.

Ekman, S.
1953. *Zoogeography of the Sea*. London: Sidgwick and Jackson.

Eliot, C. N. E.
1900 (1899). Notes on Tectibranchs and Naked Mollusks from Samoa. *Proc. Acad. Natural Sciences Philadelphia*, pp. 512-523.
1903. Nudibranchiata with Some Remarks on the Families and Genera and Description of a New Genus, *Doridomorpha*. In J. S. Gardiner, *Fauna and Geography of the Maldive and Laccadive Archipelagoes*, Vol. 2, pp. 540-573. Cambridge.
1904a (1903). On Some Nudibranchs from East Africa and Zanzibar. Part III. *Proc. Zoological Soc. London* 2:354-385.
1904b. On Some Nudibranchs from East Africa and Zanzibar. IV. Doridídae, Cryptobranchiae, II. *Proc. Zoological Soc. London* 1:380-406.
1905a. Nudibranchs from the Indo-Pacific: I. *J. Conchyliologie* 11(8):237-256.
1905b. On Some Nudibranchs from the Pacific, Including a New Genus, *Chromodoriella*. *Proc. Malacological Soc. London* 6(4):229-238.
1906. On the Nudibranchs of Southern India and Ceylon, with Special Reference to the Drawings of Kelaart and the Collections Belonging to Alder and Hancock Preserved in the Hancock Museum at Newcastle-on-Tyne. *Proc. Zoological Soc. London*, pp. 636-691.
1910. Nudibranchs Collected by Mr. Stanley Gardiner from the Indian Ocean in H. M. S. *Sealark*. *Trans. Linnaean Soc. London* 13:411-438.
1913. Japanese Nudibranchs. *J. Coll. Science Imperial Univ. Tokyo* 35:1-47.

Emerson, W. K., and W. O. Cernohorsky
1973. The Genus *Drupa* in the Indo-Pacific. *Indo-Pacific Mollusca* 3(13):801-864.

Emerson, W. K., and W. E. Old, Jr.
1965. New Molluscan Records for the Galapagos Islands. *Nautilus* 78(4):116-120.

Emory, K. P. and Y. H. Sinoto
1969. *Age Sites in the South Point Area, Ka'u, Hawaii*. Pacific Anthropological Records 8, Honolulu.

Engel, H.
1927. Westindische opisthobranchiate Mollusken: I. *Bijdr. Dierk. Leiden* 25:83-122.
1936. Über westindische Aplysiidae und Verwandte anderer Gebiete. *Capita Zoologica* 8(1):1-75.
1942. The Genus *Dolabella*. *Zoologische Meded.* 24(1-2):197-239.

Evans, T. J.
1950. A Review of Pease's Genus *Volvatella*. Together with a Preliminary Report on a New Sacoglossan Genus. *Proc. Malacological Soc. London* 28:102-106.

Eydoux, J. F. T., and F. L. A. Souleyet
1852. *Voyage autour du Monde exécuté pendant les années 1836 et 1837 sur la corvette* La Bonite. . . . Paris. Zoologique Mollusques, Vol. 2, pp. 1-664.

Fair, R.
1973. Something Old, Something New. *Hawaiian Shell News* 21(10):1, 5.
1974. Some Notes on the Genus *Homalocantha* Morch, 1842. *Hawaiian Shell News* 22(9):1, 4-5.

Fankboner, P. V.
1970. Notes on Feeding and the Functional Morphology of the Gut in the Reef Dwelling Muricid *Morule elata* Blainville. Abstr. in *The Biology of Molluscs*. Univ. Hawaii, Hawaii Inst. Marine Biology, Tech. Rep. 18, pp. 6-7.

Farmer, W.
1966. Range Extension of *Berghia amakusana* (Baba) to the East Pacific. *Veliger* 9(2):251.

Finlay, H. J.
1924. The Family Liotiidae, Iredale, in the New Zealand Tertiary. Pt. 1. The Genus Brookula. *Trans. New Zealand Inst.* 55:526-531.
1927. A Further Commentary on New Zealand Molluscan Systematics. *Trans. New Zealand Inst.* 57:320-485.

Fischer, P.
1856. Description d'espèces nouvelles. *J. Conchyliologie* 5(2):273-277.

Fleming, C. A.
1962. On the Hawaiian Scallops of the Genus *Pecten* Müller (Pelecypoda). *Pacific Science* 16(2):181-185.

Folin, L. de
1867. Descriptions d'espèces nouvelles de Caecidae. *J. Conchyliologie* 15:44-58.
1879. On the Mollusca of the H. M. S. Challenger Expedition. The Caecidae, Comprising the Genera *Parastrophia, Watsonia,* and *Caecum*. *Proc. Zoological Soc. London,* pp. 806-812.
1881. *Les Fonds de la Mer*. Paris. Vol. 4.

Forbes, E.
1852 (1850). On the Marine Mollusca Discovered During the Voyages of the *Herald* and *Pandora* by Capt. Kellett, R. N., and Lieut. Wood, R. N. *Proc. Zoological Soc. London,* pp. 270-274.

Force, R. W. and M. Force
1968. *Art and Artifacts of the 18th Century*. Honolulu: Bishop Museum Press.

Forskål, P.
1775. Vermes I: Mollusca. In *Descriptiones animalium: avium, amphibiorum, piscium, insectorum, vermium quae in itinere orientali observavit Petrus Forskål*. Copenhagen.

Forster, J. G. A.
1777. *A Voyage Round the World in H. M. S.* Resolution, *Commanded by Capt. J. Cook, During . . . 1772-1775*. 2 vols. London.

Fretter, V.
1939. The Structure and Function of the Alimentary Canal of Some Tectibranch Molluscs, with a Note on Excretion. *Trans. Royal Soc. Edinburgh* 59(3):599-646.
1943. Studies in the Functional Morphology and Embryology of *Onchidella celtica* (Forbes & Hanley) and Their Bearing on its Relationships. *J. Marine Biological Assoc. United Kingdom* 25:685-726.
1948. The Structure and Life History of Some Minute Prosobranchs of Rock Pools: *Skeneopsis planorbis* (Fabricius), *Omalogyra atomus* (Philippi), *Rissoella diaphana* (Alder) and *Rissoella opalina* (Jeffreys). *J. Marine Biological Assoc. United Kingdom* 27:597-632.

Fretter, V. (cont.)
1951. Observations on the Life History and Functional Morphology of *Cerithiopsis tubercularis* (Montagu) and *Triphora perversa* (L.). *J. Marine Biological Assoc. United Kingdom* 29:567-586.
1965. Functional Studies of the Anatomy of Some Neritid Prosobranchs. *J. Zoology* 147:46-74.
1970. Notes on Reproduction in *Mitra astricta* Linn. Abstr. in *The Biology of Molluscs*. Univ. Hawaii, Hawaii Inst. Marine Biology, Tech. Rep. 18, pp. 8-9.

Fretter, V., and A. Graham
1962. *British Prosobranch Molluscs*. London: Ray Soc.

Fretter, V., and A. M. Patil
1958. A Revision of the Systematic Position of the Prosobranch Gastropod *Cingulopsis (=Cingula) fulgida* (J. Adams). *Proc. Malacological Soc. London* 33:114-126.

Frick, D.
1856. Notes on Hawaiian Terrestrial Conchology. *Sandwich Islands Monthly Mag.* 1:137-140.

Fulton, H. C.
1915. A List of the Recent Species of *Spondylus* Linné, With Some Notes and Descriptions of Six New Forms. *J. Conchyliologie* 14(11):331-338.

Gage, R.
1962. New Geographical Record for Hawaii. *Hawaiian Shell News* 11(1):3.

Galtsoff, P. S.
1933. *Pearl and Hermes Reef, Hawaii: Hydrographical and Biological Observations*. B. P. Bishop Mus. Bull. 107. Honolulu.

Garrard, T. A.
1961. Mollusca Collected by M. V. "Challenge" off the East Coast of Australia. *J. Malacological Soc. Australia* 1(5):3-38.

Garrett, A.
1857. Mr. Garrett's Paper on New Species of Marine Shells of the South Seas. *Proc. California Acad. Sciences* 1:114-115.
1873a (1872). List of Species of Mitridae Collected at Rarotonga, Cook's Islands, with Notes, Also Descriptions of New Species. *Proc. Zoological Soc. London*, pp. 839-843.
1873b. Descriptions of New Species of Marine Shells Inhabiting the South Sea Islands. *Proc. Acad. Natural Sciences Philadelphia*, pp. 209-231.
1873c. Descriptions of New Species of Land Shells Inhabiting the South Sea Islands. *Proc. Acad. Natural Sciences Philadelphia*, pp. 233-237.
1878. Annotated Catalogue of the Species of *Conus* Collected in the South Sea Islands. *J. Conchyliologie* 1:353-367.
1879. Annotated Catalogue of the Species of Cypraeidae Collected in the South Sea Islands. *Proc. Acad. Natural Sciences Philadelphia*, pp. 209-231.
1880. Catalogue of the Polynesian Mitridae, with Remarks on their Geographical Range, Station, and Descriptions of Supposed New Species. *J. Conchyliologie* 3:1-73.

Gaskoin, J. S.
1836. [*Cypraea beckii.*] *Proc. Zoological Soc. London*, pp. 198-204.
1846. Descriptions of Three New Species of *Cypraea*. *Proc. Zoological Soc. London*, Pt. 14, pp. 23-25.
1849. Descriptions of New Species of the Genus *Cypraea*. *Proc. Zoological Soc. London*, pp. 90-98.
1852 (1851). Descriptions of Twenty Species of Collumbellidae, and One Species of *Cypraea*. *Proc. Zoological Soc. London*, Pt. 19, pp. 2-14.

Gillett, K., and F. McNeill
1959. *The Great Barrier Reef and Adjacent Isles*. Sydney: Coral Press.

Gmelin, J. F.
1791. *Caroli a Linné systema naturae per regna tria naturae*. Editio decima tertia, aucta, reformata. Vol. 1, Pt. 6, pp. 3021-3910. Leipzig.

Gohar, H. A. F., and G. N. Soliman
1964. On the Biology of Three Coralliophilids Boring in Living Corals. *Publ. Marine Biology Station Al-Ghardaqa, Egypt* 12:99-126.

Gooding, R. V., and J. Lützen
1973. Studies on Parasitic Gastropods from Echinoderms III. A Description of *Robillarida cernica* Smith, 1889, Parasitic in the Sea Urchin *Echinometra* Meuschen, With Notes on Its Biology. *Dansk Videnskarbernes Selskab Biologiske Skrifter* 20(4):1-22.

Gosline, W. A., and V. E. Brock
1960. *Handbook of Hawaiian Fishes*. Honolulu: Univ. Hawaii Press.

Gosliner, T.
1973. Aeolids of the Hawaiian Islands. Master of Science Research Rep. Univ. Hawaii, Dept. of Zoology.
In press. The Systematics of the Aeolidacea (Nudibranchia: Mollusca) of the Hawaiian Islands, with the Descriptions of Two New Species. *Pacific Science*.

Gould, A. A.
1845. [Twelve New Species of Land Shells from the Sandwich Islands.] *Proc. Boston Soc. Natural History* 2:26-28.
1846. [Shells Collected by the United States Exploring Expedition Under the Command of Charles Wilkes.] *Proc. Boston Soc. Natural History* 2:141-145; 148-152; 159-162.
1849. Shells of U. S. Exploring Expedition. *Proc. Boston Soc. Natural History* 3:83-85; 118-121; 140-144.
1850. [Shells Collected by the United States Exploring Expedition Under the Command of Charles Wilkes.] *Proc. Boston Soc. Natural History* 3:151-156; 214-219; 276-278; 309-312.
1852. Mollusca and Shells. In *United States Exploring Expedition During the Years 1839-1842 Under the Command of Charles Wilkes, U.S.N.* Vol. 12. Boston. [*Addenda and Corrigenda*, Philadelphia [1856], pp. 499-509; *Atlas*, Philadelphia, 1856 [1861].]
1859-1861. Descriptions of Shells Collected in the North Pacific Exploring Expedition Under Captains Ringgold and Rodgers. *Proc. Boston Soc. Natural History* 7:161-166 (1859); 323-336 (1860); 401-409 (1861); 8:14-32 (1861).
1862. Descriptions of New Genera and Species of Shells. *Proc. Boston Soc. Natural History* 8:280-284.

Graham, A.
1939. On the Structure of the Alimentary Canal of Style-bearing Prosobranchs. *Proc. Zoological Soc. London*, Ser. B, 109(1):75-112.

Grassett, J. P. A.
1884. *Index Testaceorum viventium quae in collectione*. Alger: J. P. A. Grassett.

Gray, E. W.
1801. Catalogue of Shells Bequeathed to the British Museum by the Rev. Clayton Mordaunt. Cracherode A. M. 98 pp. London. (MS.)

Gray, J. E.
1824-1828. Monograph on the Cypraeidae, a Family of Testaceous Mollusca. *Zoological J.* 1:71-80; 137-152; 367-391 (1824); 489-518 (1825); 3:363-371; 567-576; 4:66-88; 213-216 (1828).
1825. A List and Description of Some Species of Shells Not Taken Notice of by Lamarck: Part 1. *Ann. Philosophy* 9:135-140; 407-415.
1831. Description of New Cowries. *Zoological Misc.* 1:35.
1834a. In E. Griffith and E. Pidgeon, *The Animal Kingdom Arranged in Conformity with its Organization, by the Baron Cuvier, The Mollusca and Radiata*. London: Whittaker.
1834b. Enumeration of the Species of the Genus *Terebra*, with Characters of Many Hitherto Undescribed. *Proc. Zoological Soc. London*, pp. 59-63.
1839. Molluscous Animals and Their Shells. In: F. W. Beechey, *The Zoology of Capt. Beechey's Voyage . . . to the Pacific and Behring's Straits in His Majesty's Ship* Blossom. . . . London.
1849. *Catalogue of the Mollusca in the British Museum*. London.
1855. *List of Mollusca and Shells in the Collection of the British Museum Collection and Described by M. M. Eydoux and Souleyet*. London.
1858. Notes on some Specimens of *Cypraea* (Cowries) from the Sandwich Islands. *Ann. Mag. Natural History* (3rd Ser.) 11(8):49-50.

Gray, J. E., and G. B. Sowerby
1839. *The Zoology of Capt. Beechey's Voyage . . . to the Pacific and Behring's Straits . . . in 1825-28. Molluscous Animals and their Shells*. London.

Green, J. C.
1827. Description of Two New Species of *Achatina* from the Sandwich Islands — with some Remarks on the Ti, the Plant on which these Shells are Commonly Found. *Maclurian Lyceum Contrib.* 1:47-50.

Greene, K.
1953. Best Specimens. *Hawaiian Shell News* 2(2):9.

Griffiths, R. J.
1959. Subspeciation in Two Species of Cypraeidae. *Proc. Malacological Soc.* 33(5):176-185.

Grigg, R. W.
1964. A Contribution to the Biology and Ecology of the Black Coral, *Antipathes grandis* in Hawaii. Master of Science Thesis, Univ. Hawaii, Honolulu, Hawaii.

Gross, M. G., J. D. Milliman, J. I. Tracey, Jr., and H. S. Ladd
1969. Marine Geology of Kure and Midway Atolls, Hawaii. A Preliminary Report. *Pacific Science* 23(1):17-25.

Guinther, E.
1970. Biology of Some Hawaiian Epitoniidae. Abstr. in *The Biology of Mollusca*. Univ. Hawaii, Hawaii Inst. Marine Biology Tech. Rep. 1:10-11.

Gulick, A.
1932. *Evolutionist and Missionary John Thomas Gulick*. Chicago: Univ. Chicago Press.

Gulick, J. T.
1905. *Evolution Racial and Habitudinal*. Carnegie Inst. Washington Pub. No. 25.

Habe, T.
1952. Atyidae in Japan. In T. Kuroda, *Illustrated Catalogue of Japanese Shells*, Vol. 20, pp. 137-152.
1961a. *Coloured Illustrations of the Shells of Japan*. Vol. 2. Osaka: Hoikusha.
1961b. Three New Gastropods from Japan. *Venus* 21(3):270-274.
1961c. Description of Fifteen New Species of Japanese Shells. *Venus* 21(3):416-431.
1964. *Shells of the Western Pacific*. Vol. 2. Osaka: Hoikusha.
1972. Japan's Smallest Gastropod, *Ammonicera japonica*, sp. nov. *Venus* 31(3):115-116.
1977. New and Little Known Bivalves of Japan. *Venus* 36(1):1-12.

Habe, T., and S. Kosuge
1964. *A List of the Indo-Pacific Molluscs, Concerning to the Japanese Molluscan Fauna (2), Class Gastropoda (Superfamily Stromboidea)*. 14 pp.
1970. Descriptions of Three New Gastropods from the Sea around Midway Islands., *Venus* 29(3):87-92.

Habe, T., and T. Okutani
1968. Some New and Interesting Shells from the Sea Around Midway Island. *Venus* 27(2):47-56.

Hadfield, M. G.
1966. The Reproductive Biology of the California Vermetid Gastropods *Serpulorbis squamigerus* (Carpenter, 1857) and *Petaloconchus montereyensis* Dall, 1919. Ph.D. Dissertation, Stanford Univ.
1972. Flexibility in Larval Life Patterns. *American Zoologist* 12(4):602.
1976. Molluscs Associated with Living Tropical Corals. *Micronesica* 12:133-148.

Hadfield, M. G., and R. H. Karlson
1969. Externally Induced Metamorphosis in a Marine Gastropod. *American Zoologist* 9(4):317.

Hadfield, M. G., E. A. Kay, M. V. Gillette, and M. C. Lloyd
1972. The Vermetidae (Mollusca: Gastropoda) of the Hawaiian Islands. *Mar. Biol.* 12(1):81-98.

Haefelfinger, H.-R., and R. A. Stamm
1958. *Limenandra nodosa* gen. et spec. nov. (Nudibranch., Aeolidiidae propr.) un Opisthobranche nouveau de la Mediterranee. *Vie et Milieu* 9:418-423.

Halstead, B. W.
1965. *Poisonous and Venomous Marine Animals of the World. I, Invertebrates*. Washington, D. C.: U. S. Gov't Printing Office.

Hanna, G. D.
1966. *Introduced Mollusks of Western North America*. Occ. Pap. California Acad. Sci. 48, 108 pp.

Hanley, S.
1844. Descriptions of New Species of *Tellina*, Collected by H. Cuming, Esq. *Proc. Zoological Soc. London*, Pt. 12, pp. 59-64; 164-166.

Harris, L. G.
1968. Notes on the Biology and Distribution of the Aeolid Nudibranch (Gastropoda), *Phestilla melanobrachia* Bergh, 1874. *Publ. Seto Marine Biological Laboratory* 16(3):193-198.
1975. Studies on the Life History of Two Coral-eating Nudibranchs of the Genus *Phestilla*. *Biological Bull.* 149:539-550.

Harrison, I., B. Harrison, and A. Harrison
1966. Field Collecting Hawaiian *Cymatium*. *Hawaiian Marine Mollusks* 2(28):1.

Hartmann, W. D.
1888. A Bibliographic and Synonymic Catalogue of the Genus *Achatinella*. *Proc. Acad. Natural Sciences Philadelphia* pp. 16-56.

Hasselt, J. C. van
1824. [In Férussac]. Extrait d'une lettre du Dr. F. C. van Hasselt au Prof. van Swinderen sur mollusques de Java. *Bull. Sci. Naturelle* 3:237-248.

Hatai, K., H. Niino, and T. Kotaka
1952. On the Bottom Characters of the Insular Shelf Around Hachijo Island and the Neighboring Banks. *J. Tokyo Univ. Fisheries* 39:101-110.

Heath, H.
1910. A New Genus of Parasitic Gastropods. *Biological Bull.* (Woods Hole, Mass.) 18:99-108.
1911. *Scientific Results of the Expedition to the Tropical Pacific, in Charge of Alexander Agassiz, by the U. S. Fish Commission Steamer* Albatross, *from August 1899, to June 1900. . . . XIV. The Solenogastres*. Mem. Mus. Comparative Zoology Harvard 45. 179 pp.

Hedley, C. A.
1899. The Mollusca of Funafuti. *Mem. Australian Mus.* 3:395-510; 491-535; 549-565.
1902. Studies on Australian Mollusca, Part 7. *Proc. Linnaean Soc. New South Wales* 27:596-619.
1904. Studies on Australian Mollusca, Part 8. *Proc. Linnaean Soc. New South Wales* 29:182-211.
1907. The Mollusca of Mast Head Reef, Capricorn Group, Queensland. *Proc. Linnaean Soc. New South Wales* 32(3):476-513.
1909. Mollusca from the Hope Islands, North Queensland. *Proc. Linnaean Soc. New South Wales* 34(3):420-466.
1913. Studies on Australian Mollusca, Part II. *Proc. Linnaean Soc. New South Wales* 38:258-339.
1916. Studies on Australian Mollusca: Part XIII. *Proc. Linnaean Soc. New South Wales* 41:680-719.
1922. A Revision of the Australian Turridae. *Rec. Australian Mus.* 13(6):213-259.
1924. Some Naticoids from Queensland. *Rec. Australian Mus.* 14(3):154-162.

Helbling, G. S.
1779. Beitrage zur Kenntniss neuer und seltener Konchylien. *Abhandlung Privatges*, Bohmen 4:102-131.

Helfrich, P.
1971. University of Hawaii Proposal to Office of Sea Grant, National Oceanic and Atmospheric Administration, U. S. Dept. of Commerce.

Henderson, J.
1927. Conchological Notes from the Hawaiian Islands. *Nautilus* 40:80-82.

Hertlein, L. G.
1935. Notes on the Pectinidae of Hawaii. *Nautilus* 49:27-29.
1937. A Note on Some Species of Marine Mollusks Occurring in Both Polynesia and the Western Americas. *Proc. American Philosophical Soc.* 78(2):303-312.

Hertlein, L. G., and E. C. Allison
1966. Additions to the Molluscan Fauna of Clipperton Island. *Veliger* 9(2):138-140.

Hervier, R. P. J.
1895. Descriptions d'espèces nouvelles de mollusques, provenant de l'Archipel de la Nouvelle-Calédonie. *J. Conchyliologie* 43:141-152; 44:51-95.
1897. Descriptions d'espèces nouvelles de mollusques provenant de la Nouvelle-Calédonie. *J. Conchyliologie* 45:249-266.

Hervier, R. P. J. (cont.)
1898. Descriptions d'espèces nouvelles de mollusques, provenant de l'Archipel de la Nouvelle-Calédonie. *J. Conchyliologie* 46:47-69; 225-248.
1899. Le genre *Columbella* dans l'Archipel de la Nouvelle-Calédonie. *J. Conchyliologie* 47:305-391.

Hida, T. S.
1957. *Chaetognaths and Pteropods as Biological Indicators in the North Pacific*. U. S. Dept. Interior, Fish and Wildlife Service, Special Scientific Rep. Fisheries No. 215.

Higgins, J. H.
1969. Some Aspects of the Ecology of a Bivalve Mollusk in Kaneohe Bay, Oahu. Master of Science Thesis, Univ. Hawaii, Honolulu, Hawaii.

Hinds, R. B.
1843. Descriptions of New Shells from the Collection of Capt. Belcher. *Ann. Mag. Natural History* (1)11:16-21.
1844. Descriptions of New Shells, Collected During the Voyage of the Sulphur and in Mr. Cuming's Late Visit to the Philippines. *Ann. Mag. Natural History* 14:63-75.
1968. The Sandwich Islands. From Richard Brinsley Hinds' Journal of the Voyage of the "Sulphur" (1836-1842). E. A. Kay (ed.). *Hawaiian J. History* 2:102-135.

Hirase, Y.
1907-1909. On Japanese Marine Mollusca, Parts 1-12. *Conchological Mag. Japan*, Vols. 1-3.

Hobson, E. S.
1974. Feeding Relationships of Teleostean Fishes on Coral Reefs in Kona, Hawaii. *Fishery Bull.* 72(4):915-1031.

Hoeven, J. van der
1839. Tijdschr. voor natuurl. Geschied. *Bull. Scienc. Phys. Neerlande*, pp. 245-247.

Hoffmann, H.
1928. Zur kenntnis der Oncidiiden (Gastrop. pulmon.) 1. Teil. Untersuchung neuen Materials und Revision der Familie. *Zoologische Jahrb. Syst.* 55(1-3):29-118.

Holthuis, L. B.
1973. Caridean Shrimps Found in Land-locked Saltwater Pools at Four Indo-West Pacific Localities (Sinai Peninsula, Funafuti Atoll, Maui and Hawaii Islands), with the Descriptions of One New Genus and Four New Species. *Zooligische verhandel* 128:1-48.

Hoskin, G. P.
1968. The Comparative Biology and Morphology of the Parasitic Prosobranchs *Mucronalia nitidula* Pease, 1860, and *Mucronalia* n. sp. Master of Science Thesis, Univ. Hawaii, Honolulu, Hawaii.

Hoskin, G. P., and T. C. Cheng
1968. On the Ecology and Microanatomy of the Parasitic Marine Prosobranch *Mucronalia nitidula* (Pease, 1860). Symposium on Mollusca, Ernakulam, India. *Proc. Marine Biological Assoc. India*, Pt. 3.

Houbrick, J. R., and V. Fretter
1969. Some Aspects of the Functional Anatomy and Biology of *Cymatium* and *Bursa*. *Proc. Malacological Soc. London* 38:415-429.

Houbrick, R. S.
1973. Reproductive Biology of *Cerithium*. *Bull. Marine Sci.* 23(4):875-904.
1974. The Genus *Cerithium* in the Western Atlantic. *Johnsonia* 5(50):33-84.
1978. The Family Cerithiidae in the Indo-Pacific. Pt. I. The Genera *Rhinoclavis*, *Pseudovertagus*, and *Clavocerithium*. *Monogr. Marine Mollusca* No. 1.

Hoyle, W. E.
1886. Report on the Cephalopoda Collected by H. M. S. *Challenger*, During the Years 1873-76. *Report Scientific Results Voyage of* Challenger, *Zoology*, Vol. 16. 246 pp.

Hubendick, B.
1956. A Conchological Survey of the Genus *Plectotrema* (Gastropoda: Ellobiidae). *Proc. Malacological Soc. London* 32(1):110-126.

Humphrey, G.
1797. *Museum Calonnianum. Specification of the Various Articles which Compose the . . . Museum of Natural History, Collected by M. de Calonne in France. . . .* Pt. 1. London.

Hurst, A.
1965. Studies on the Structure and Function of the Feeding Apparatus of *Philine aperta* with Comparative Consideration of Some Other Opisthobranchs. *Malacologia* 2:281-347.
1967. The Egg Masses and Veligers of Thirty Northeast Pacific Opisthobranchs. *Veliger* 9:255-288.

Hutchinson, G. E.
1965. *The Ecological Theater and the Evolutionary Play*. New Haven: Yale Univ. Press.

Hwass, C.
1792. In Bruguiére, J. G. Cone. *Encyclopédie méthodique. Histoire naturelle des Mollusques*. Paris.

Hyman, L. H.
1967. *The Invertebrates*. Vol. 6, *Mollusca I*. 792 pp. New York: McGraw-Hill.

Hynd, J. S.
1955. A Revision of the Australian Pearl-Shells, Genus *Pinctada* (Lamellibranchia). *Australian J. Marine and Freshwater Res*. 6(1):98-137.

Ingram, W. M.
1936. A Reduction of *Cypraea annae* Roberts and *Cypraea polita* Roberts to synonymy with *Cypraea semiplota* Mighels. *Nautilus* 50(2):51-52.
1937. The Family Cypraeidae in the Hawaiian Islands. *Nautilus* 50(3):77-82.
1939a. Endemic Hawaiian Cowries. *B. P. Bishop Mus. Occ. Pap*. 14(19):327-333.
1939b. Cypraeidae from American Samoa with Notes on Species from Palmyra Island. *Nautilus* 52(3):103-105.
1939c. *Atys semistriata* Pease in Kaneohe Bay, Oahu, Hawaiian Islands. *Nautilus* 52(4):117-123.
1943. Comments on F. A. Schilder's "Cypraeacea from Hawaii," and Schilder and Schilder's "Prodrome of a Monograph on Living Cypraeidae." *Nautilus* 57(1):22-27.
1947. Hawaiian Cypraeidae. *B. P. Bishop Mus. Occ. Pap*. 19(1):1-23.

Iredale, T.
1910. On Marine Molluscs from the Kermadec Islands and on the Sinusigera Apex. *Proc. Malacological Soc. London* 9:68-79.
1912. New Generic Names and New Species of Marine Mollusca. *Proc. Malacological Soc. London* 10:217-228.
1916. On Some New and Old Molluscan Generic Names. *Proc. Malacological Soc. London* 12(1):27-37.
1927. A Review of Australian Helmet Shells (Cassididae). *Rec. Australian Mus*. 15:321-354.
1929a. Strange Molluscs in Sydney Harbour. *Australian Zoologist* 5:337-352.
1929b. Queensland Molluscan Notes, No. 1. *Mem. Queensland Mus*. 9:261-297.
1929c. Mollusca from the Continental Shelf of Eastern Australia, No. 2. *Rec. Australian Mus*. 17:157-189.
1937. The Middleton and Elizabeth Reefs, South Pacific Ocean. Mollusca. *Australian Zoologist* 8:287-333.
1939a. Australian Cowries, Part 2. *Australian Zoologist* 9:297-323.
1939b. *Mollusca. Pt. I. Great Barrier Reef Expedition 1928-29*. British Mus. (Natural History). Vol. 5, No. 6.

Iredale, T., and D. F. McMichael
1962. A Reference List of the Marine Mollusca of New South Wales. *Mem. Australian Mus*. 11:1-109.

Iredale, T., and J. R. le B. Tomlin
1917. *Lienardia mighelsi* nom. nov. *J. Conchology* 15:216.

Issel, A.
1869. *Malacologia del Mar Rosso richerche Zoologiche e paleontologiche*. Pisa.

Ivanov, A. V.
1952. Structure of the Parasitic Gastropods Stiliferidae as the Result of their Mode of Life. *Trudy leningr. Obschch. Estst*. 71:86-140 (in Russian).

Jameson, H. L.
1901. On the Identity and Distribution of the Mother-of-Pearl Oysters; with a Revision of the Subgenus *Margaritifera*. *Proc. Zoological Soc. London*, pp. 372-394.

Jarves, J. J.
1838. Sketches of Kauai. *Hawaiian Spectator* 1:66-86.
Jay, J. C.
1828. *Catalogue of Recent Shells*. (2nd ed.) New York.
1839. *A Catalogue of Shells*. (3rd ed.) New York.
Johannes, R. E.
1963. A Poison-secreting Nudibranch (Mollusca: Opisthobranchia). *Veliger* 5(3):104-105.
Johnson, R. I.
1964. *The Recent Mollusca of Augustus Addison Gould*. Bull. U. S. National Mus. 239, 182 pp.
Jonas, J. H.
1845. Neue conchylien. *Z. Malakozoologie* 1845:169-171.
Jousseaume, F. P.
1875. Coquilles de la famille des Marginelles. Monographie. *Rev. Mag. Zoologique* 3(3):164-271; 429-435.
1884. Monographie des Triforidae. *Bull. Soc. Malacologique France* 9:217-270.
1931. Cerithiidae de la Mer Rouge. *J. Conchyliologie* 74:270-296.
Kaicher, S. D.
1956. *Indo-Pacific Sea Shells*. Toxoglossa. Washington, D. C.
Kawaguti, S.
1943. Notes on *Phestilla sibogae* with Symbiotic Zooxanthellae. *Taiwan Natural History Mag.* 33:298-299.
Kawaguti, S., and K. Baba
1959. A Preliminary Note on a Two-Valved Sacoglossan Gastropod *Tamanovalva limax* n. gen. from Tamano, Japan. *Biological J. Okayama Univ.* 5:177-184.
Kawaguti, S., and T. Yamasu
1966. Feeding and Spawning Habits of a Bivalved Gastropod, *Julia japonica*. *Biological J. Okayama Univ.* 12:1-9.
Kawamoto, P. Y., and H. M. Sakuda
1973. *Commercial Oyster Fishery Development Investigation*. Completion Report, National Marine Fisheries Service Project H-2-RIH-13-R. State of Hawaii, Dept. of Land and Natural Resources, Div. of Fish and Game. 13 pp. (Mimeo.)
Kay, E. A.
1949. Some Edible Mollusks of Kauai, Hawaiian Islands. *Nautilus* 62(4):119-121.
1961a. On *Cypraea tigris schilderiana* Cate. *Veliger* 4:36-40.
1961b. A Zoogeographical Analysis of Species of *Cypraea* in the Hawaiian Islands. *Proc. Malacological Soc. London* 34:185-198.
1961c. A New Opisthobranch Mollusc from Hawaii. *Pacific Science* 15(1):112-113.
1964a. A New Species of *Berthelinia* and its Associated Sacoglossans in the Hawaiian Islands. *Proc. Malacological Soc. London* 36:191-197.
1964b. The Aplysiidae of the Hawaiian Islands. *Proc. Malacological Soc. London* 36:173-190.
1965. Marine Molluscs in the Cuming Collection, British Museum (Natural History) described by William Harper Pease. *Bull. British Museum (Natural History)*, Zoology, Suppl. 1.
1967a. The Composition and Relationships of the Marine Molluscan Fauna of the Hawaiian Islands. *Venus* 25:96-104.
1967b. Name Changes for *Terebra funiculata* Hinds and *T. langfordi* Pilsbry. *Hawaiian Shell News* 15(7):1.
1967c. A Pearl from an Opihi. *Hawaiian Shell News* 15(11):1.
1971. The Littoral Marine Molluscs of Fanning Island. *Pacific Science* 25(2):260-281.
1976. Molluscan Distribution Patterns at Canton Atoll. In S. V. Smith and R. S. Henderson (eds.), *An Environmental Survey of Canton Atoll*. Naval Undersea Research and Developmental Center, San Diego.
1977. Introduction to the Revised Edition. In D. M. Devaney and L. G. Eldredge (eds.), *Reef and Shore Fauna of Hawaii. Section 1: Protozoa through Ctenophora*. B. P. Bishop Museum Special Publication 64(1).
Kay, E. A., and M. F. Switzer
1974. Molluscan Distribution Patterns in Fanning Island Lagoon and a Comparison of the Mollusks of the Lagoon and Seaward Reefs. *Pacific Science* 28(3):275-295.

Kay, E. A., and C. S. Weaver
1962-1964. Hawaiian Marine Mollusks. *Hawaiian Shell News* (insert) 2(20-25):75-98.
Kay, E. A., and D. K. Young
1969. The Doridacea (Opisthobranchia: Mollusca) of the Hawaiian Islands. *Pacific Science* 23(2):172-231.
Keen, A. M.
1958. *Sea Shells of Tropical West America*. California: Stanford Univ. Press.
1966. West American Mollusk Types at the British Museum (Nat. Hist.), I. T. A. Conrad and the Nuttall Collection. *Veliger* 8(3):167-172.
1971. *Sea Shells of Tropical West America* (2nd ed.) California: Stanford Univ. Press.
Kelaart, E. F.
1858. Description of New and Little Known Species of Ceylon Nudibranchiate Molluscs and Zoophytes. *J. Royal Asiatic Soc. Ceylon Branch* (Colombo) 3:84-139.
1859. Descriptions of New and Little Known Species of Ceylonese Nudibranchata Molluscs. *Ann. Mag. Natural History* (Ser. 3) 3:291-304; 488-496.
Kempf, M., and J. Laboriel
1968. Formations de vermets et d'algues calcaires sur les côtes du Brasil. *Rec. Traveaux Station Marine Endoume* 43(59):9-23.
Kent, H.
1965. *Charles Reed Bishop: Man of Hawaii*. Palo Alto: Pacific Books.
Kenyon, A. F.
1898. Note on *Cypraea caputanguis*. *Proc. Malacological Soc. London* 3:77.
1900. On Two New *Cypraea*. *Proc. Malacological Soc. London* 4:68-69.
Kerslake, J.
1968. A Note on *Epitonium (Gyroscala) perplexus* Pease in Australia (Gastropoda: Epitoniidae). *J. Malacological Soc. Australia* 11:68-70.
Kiener, L. C.
1834-1870. *Spécies général et iconographie des coquilles vivantes* . . . (continué par . . . P. Fischer). Vols. 1-11. Paris.
King, J. E., and I. I. Ikehara
1956. Comparative Study of Food of Bigeye and Yellowfin Tuna in the Central Pacific. *Fishery Bull.* 108, *U. S. Fish and Wildlife Service* 57:61-85.
Kira, T.
1956. A Remarkable Ecological Form of *Apollon pusillus*. *Venus* 19:122-124.
1962. *Shells of the Western Pacific in Color*. Osaka: Hoikusha.
Kirch, P. V.
1974. The Chronology of Early Hawaiian Settlement. *Archaeology and Physical Anthropology in Oceania* 9(2):110-119.
Knudsen, J.
1950. Egg Capsules and Development of Some Marine Prosobranchs from Tropical West Africa. *Atlantidae Rep.* 1:85-130.
1967. The Deep-sea Bivalvia. The John Murray Expedition 1933-34. *Scientific Rep., British Museum (Natural History)* 11(3):237-343.
Kobelt, W.
1896. Die Familie Bullidae. *Conchylien Cabinet* Vol. 1, No. 9.
Kofoid, C. A., and R. C. Miller
1927. Biological Section. In C. L. Hill and C. A. Kofoid (eds.), *Marine Borers and Their Relation to Marine Construction on the Pacific Coast*. San Francisco Bay Marine Piling Comm., San Francisco, pp. 188-343.
Kohn, A. J.
1959a. The Ecology of *Conus* in Hawaii. *Ecological Monogr.* 29:47-90.
1959b. The Hawaiian Species of *Conus* (Mollusca: Gastropoda). *Pacific Science* 13:368-401.
1961. Studies on Spawning Behavior, Egg Masses, and Larval Development in the Gastropod Genus *Conus*, Part I. Observations on Nine Species in Hawaii. *Pacific Science* 15:163-179.
1962. Dr. Kohn on *Conus spiceri*. *Hawaiian Shell News* 11(2):8.
1963. Venomous Marine Snails of the Genus *Conus*. In *Venomous and Poisonous Animals and Noxious Plants of the Pacific Area*. Oxford: Pergamon Press.

Kohn, A. J. (cont.)
1970. Food Habits of the Gastropod *Mitra litterata* Lamarck: Relation to Trophic Structure of the Intertidal Marine Bench Community in Hawaii. *Pacific Science* 29(4):483-486.

Kohn, A. J., and C. S. Weaver
1962. Additional Records and Notes on *Conus* (Mollusca: Gastropoda) in Hawaii. *Pacific Science* 16:349-358.

Kosuge, S.
1961a. On the Family Triphoridae (Gastropoda) from Amami Islands (1). *Venus* 21:308-316.
1961b. On the Family Triphoridae (Gastropoda) from Amami Islands (2). *Venus* 21:413-415.
1962a. Descriptions of 10 New Species and 1 New Subspecies of the Family Triphoridae (Mollusca) from Shiono-misaki, Kii Peninsula, Central Japan with a List of Hitherto Known Species. *Bull. National Sci. Mus.* (Tokyo) 6:78-89.
1962b. On the Family Triphoridae (Gastropoda) from Amami Islands (3). *Venus* 22:119-129.
1963a. On the Family Triphoridae (Gastropoda) from Amami Islands (4). *Venus* 22:240-257.
1963b. On the Family Triphoridae (Gastropoda) from Amami Islands (5). *Venus* 22:257-263.
1966. The Family Triphoridae and its Systematic Position. *Malacologia* 4(2):297-324.
1969. Fossil Mollusks of Oahu, Hawaii Islands. *Bull. National Sci. Mus.* (Tokyo) 12(4):783-794.

Kotzebue, O. von
1821. *A Voyage of Discovery into the South Seas and Bering's Straits.* London: Longman, Hurst, Rees, Orme, and Brown. (Reprint. New York: Da Copo Press, 1967.)

Kuroda, T.
1949. On *Argyropeza izekiana* Kuroda n. sp. *Venus* 15(5-8):76-77.
1953. New Genera and Species of the Japanese Gastropoda (1). *Venus* 17(4):179-185.

Kuroda, T., and T. Habe
1952. *Check List and Bibliography of the Recent Mollusca of Japan.* 210 pp. Tokyo: Stach.

Kuster, H. C.
1839-1841. *Systematisches Conchylien-Cabinet von Martini und Chemnitz Funtten Bandes zweite Abtheilung Die Familie der Walzenschnecken (Volutacea Menke).* Nürnberg.

Ladd, H. S.
1966. *Chitons and Gastropods (Haliotidae through Adeorbidae) from the Western Pacific Islands.* U. S. Geological Survey Prof. Pap. 531.
1972. *Cenozoic Fossil Mollusks from Western Pacific Islands; Gastropods (Turritellidae through Strombidae).* U. S. Geological Survey Prof. Pap. 532.

Ladd, H. S., J. I. Tracey, Jr., and M. G. Gross
1967. Drilling on Midway Atoll, Hawaii. *Science* 156(3778):1088-1095.

Laevastu, T., D. E. Avery, and D. C. Cox
1964. *Coastal Currents and Sewage Disposal in the Hawaiian Islands.* HIG-64-1. Hawaii Institute of Geophysics. University of Hawaii.

Lamarck, J. B. P.
1801. *Système des Animaux sans Vertèbres.* Paris.
1810. Sur la détermination des espèces. *Ann. Mus. d'Histoire Naturelle Paris* 15:20-40; 263-286; 422-442.
1811. Sur la détermination des espèces parmi les animaux sans vertèbres, et particulièrement parmi les mollusques testacés. *Ann. Mus. d'Histoire Naturelle Paris* 17:195-222.
1816. *Tableau Encyclopédeque et méthodique des trois régnes de la nature.* Paris.
1818-1822. *Histoire naturelle des animaux sans vertèbres: Mollusques.* Paris.

Lamy, E.
1907. Révision des *Arca* vivants du Muséum d'Histoire naturelle de Paris. *J. Conchyliologie* 55:199-307.
1924. Révision des Saxicavidae vivants du Muséum National d'Histoire naturelle de Paris. *J. Conchyliologie* 68:218-248.

Laseron, C. F.
1951. Revision of the New South Wales Cerithiopsidae. *Australian Zoologist* 11(4):351-368.
1953. Minute bivalves from New South Wales. *Rec. Australian Mus.* 23(2):33-53.
1954. Revision of the New South Wales Triphoridae. *Rec. Australian Mus.* 23:139-158.
1955. The Family Cerithiopsidae (Mollusca) from the Solanderian and Dampierian Zoogeographical Provinces. *Australian J. Marine and Freshwater Res.* 7:151-182.

Laseron, C. F. (cont.)
1956. The Families Rissoinidae and Rissoidae (Mollusca) from the Solanderian and Dampierian Zoogeographical Provinces. *Australian J. Marine and Freshwater Res.* 7(3):384-484.
1957. A New Classification of the Australian Marginellidae (Mollusca), with a Review of Species from the Solanderian and Dampierian Zoogeographical Provinces. *Australian J. Marine and Freshwater Res.* 8:274-311.
1958a. Liotiidae and Allied Molluscs from the Dampierian Zoogeographical Province. *Rec. Australian Mus.* 24(11):165-182.
1958b. The Family Triphoridae (Mollusca) from Northern Australia; also Triphoridae from Christmas Island (Indian Ocean). *Australian J. Marine and Freshwater Res.* 9:569-657.
1959. The Family Pyramidellidae (Mollusca) from Northern Australia. *Australian J. Marine and Freshwater Res.* 10:177-267.

Laursen, D.
1953. *The Genus Ianthina.* Dana Report, No. 38.

Laws, C. R.
1937. A Review of the Tertiary and Neozelanic Pyramidellid Mollusca. No. 1 — the Turbonillid Genera. *Rec. Auckland Inst. Mus.* 67:402-422.

Laws, H. M.
1970. Reproductive Biology and Shell Site Preferences in *Hipponix conicus* (Schumacher) (Gastropoda: Hipponicidae). *Veliger* 13:115-121.

Leach, W. E.
1814-1817. *The Zoological Miscellany: Being Descriptions of New, or Interesting Animals.* London. 3 vols. Vol. 1 (1814), Vol. 2 (1815), Vol. 3 (1817).

Lebour, M. V.
1933. The Life-histories of *Cerithiopsis tubercularis* (Montagu), *C. barleeia* Jeffreys and *Triphora perversa* (L.) *J. Marine Biological Assoc. U. K.* 18(2):491-498.

Lesson, R. P.
1830. *Voyage autour du monde . . . sur . . . la Coquille pendant . . . 1822-25 . . . par L. J. Duperry.* Paris, Zoologie, Vol. 2, Pt. 1, pp. 1-471, Atlas.
1842a. Notes sur quelques coquilles marines Rapportées de la mer Sud. *Rev. Zoologique Soc. Cuvierienne* 5:184-187.
1842b. Mollusques recueillis dans la mer du Sud. *Rev. Zoologique Soc. Cuvierienne* 5:210-214.

Lever, A.
1806. *Catalogue of the Leverian Museum.* 7 parts and Appendix. London.

Lewis, H.
1972. Notes on the Genus *Distorsio* (Cymatiidae) with Descriptions of New Species. *Nautilus* 86(1-2):27-50.
1974. A New Species of Hawaiian *Gyrineum* (Cymatiidae). *Nautilus* 88(1):10-13.

Lewis, J. R.
1964. *The Ecology of Rocky Shores.* London: English Universities Press.

Lightfoot, J.
1786. *A Catalogue of the Portland Museum . . . Which Will Be Sold by Auction. . . .* London.

Link, H. F.
1807. *Beschreibung der Naturalien-Sammlung der Universität zu Rostock.* Dritte Abtheilung. Rostock.

Linnaeus, C.
1758. *Systema naturae per regna tria naturae.* (Editio decima, reformata.) Stockholm.
1767. *Systema naturae per regna tria naturae.* (Editio duodecima, reformata.) Stockholm, Vol. 1, *Regnum animate,* Pt. 2.

Littler, M. M.
1973. The Population and Community Structure of Hawaiian Fringing-Reef Crustose Corallinaceae (Rhodophyta, Cryptonemiales). *J. Experimental Marine Biology Ecol.* 11:103-120.

Lutzen, J.
1972. Studies on Parasitic Gastropods from Echinoderms, II. On *Stilifer* Broderip, with Special Reference to the Structure of the Sexual Apparatus and Reproduction. *Det. Kongelige Dansk Vidensk Selsk. Biol. Skrift.* 19(6):1-18.

Lutzen, J., and K. Nielsen
1975. Contributions to the Anatomy and Biology of *Echineulima* n.g. (Prosobranchia: Eulimidae), Parasitic on Sea Urchins. *Videns. Meddelelser Fra Dansk Naturhistorisk Forening* 138:171-199.

Lyman, H.
1906. *Hawaiian Yesterdays*. Chicago: McClung.

Lynge, H.
1909. The Danish Expedition to Siam, 1899-1900. IV. Marine Lamellibranchiata. *Vidensk. Selsk. Skrift, Kbh.* 3:97-299.

McClellan, E. N.
1938. Hawaiian Oysters. *Paradise of the Pacific* 50(3):27-28, 38-39.

McDowall, J.
1974. Live *Fusinus undatus* from Kauai. *Hawaiian Shell News* 22(1):8.

MacFarland, W. F.
1918. The Dolabellinae. *Mem. Mus. Comparative Zoology, Harvard* 35:300-348.

McLean, J. H.
1967. West American Scissurellidae. *Veliger* 9(4):404-410.
1969. The Families Liotiidae and Skeneidae in the Eastern Pacific. *Echo* No. 2, p. 18.
1971. A Revised Classification of the Family Turridae, with the Proposal of New Subfamilies, Genera, and Subgenera from the Eastern Pacific. *Veliger* 14(1):114-130.

MacNae, W.
1954. On Four Sacoglossan Molluscs New to South Africa. *Ann. Natal Mus.* 13(1):51-64.
1955. On Four Species of the Genus *Aplysia* Common in South Africa. *Ann. Natal Mus.* 13(2):223-241.
1958. The Families Polyceridae and Goniodorididae (Mollusca, Nudibranchiata) in Southern Africa. *Trans. Royal Soc. South Africa* 35:341-372.
1962. Tectibranch Molluscs from South Africa. *Ann. Natal Mus.* 15(16):183-199.

MacNae, W., and M. Kalk
1958. A Natural History of Inhaca Island, Mozambique. Johannesberg: Witwatersrand Univ. Press.

MacNeil, F. S.
1960. *Tertiary and Quaternary Gastropoda of Okinawa*. U. S. Geological Survey Prof. Pap. 339, 148 p.

Macrae, J.
1922. With Lord Byron at the Sandwich Islands in 1825. Being Extracts from the Ms. Diary of James Macrae, Scottish Botanist. W. F. Wilson, (ed.). Honolulu.

Maciolek, J.
In press. Shell Character, Habitat, and Other Notes on Nonmarine Hawaiian Neritid Snails. *Pacific Science*.

Maes, V. O.
1966. Sexual Dimorphism in the Radula of the Muricid Genus *Nassa*. *Nautilus* 79(3):73-80.
1967. The Littoral Marine Mollusks of Cocos Keeling Islands (Indian Ocean). *Proc. Acad. Natural Sciences Philadelphia* 119(4):93-217.

Maes, V., and D. Raeihle
1975. Systematics and Biology of *Thala floridana* (Gastropoda: Vexillidae). *Malacologia* 15(1):43-67.

Malo, D.
1951. *Hawaiian Antiquities*. B. P. Bishop Museum Spec. Publ. 2. (2nd ed.) Honolulu.

Mant, C. F.
1923. Mollusca from Dredging Operations at Kewalo Harbor, Honolulu, 1921. *Nautilus* 36:120-123.

Maragos, J. E.
1972. A Study of the Ecology of Hawaiian Reef Corals. Ph.D. Dissertation, Univ. Hawaii. Honolulu, Hawaii.
1974. *Reef Corals of Fanning Island. Fanning Island Expedition, July and August 1972*. Hawaii Inst. Geophysics, Univ. Hawaii, HIG-73-13:97-110.

Marcus, E.
1956. Notes on Opisthobranchia. *Bol. Inst. Oceanográfico São Paulo* 7(1):31-78, pls.
1957. On Opisthobranchia from Brazil 2. *J. Linnaean Soc. London* 43(292):390-486.
1958. *On Western Atlantic Opisthobranchiate Gastropods*. American Museum Novitates No. 1906, pp. 1-82.
1960 (1959). Opisthobranchia aus dem Roten Meer und von den Malediven. *Abhandl. Akad. der Wissench. und der Lit. Mainz* 12:871-934.
1965. Some Opisthobranchia from Micronesia. *Malacologia* 3(2):263-286.

Marcus, E., and J. B. Burch
1965. Marine Euthyneuran Gastropoda from Eniwetok Atoll, Western Pacific. *Malacologia* 3(2):235-262.

Marcus, E., and E. du B. R. Marcus
1959. Some Opisthobranchs from the Northwestern Gulf of Mexico. *Publ. Inst. Marine Science Texas* 6:251-264.
1962. Studies on Columbellidae. *Bol. Fac. Fil. Cien. Letr. Univ. São Paulo (261), Zool.* 24:335-402.
1967a. Opisthobranchs from the Gulf of California. *Studies Tropical Oceanography Miami* 6(2):141-248.
1967b. Tropical American Opisthobranchs. *Studies Tropical Oceanography Miami* 6(1):3-137.

Marcus, E. du B. R.
1976. On *Kentrodoris* and *Jorunna* (Gastropoda, Opisthobranchia). *Bol. de Zoologique Univ. São Paulo* 1:11-68.

Marin, D. F. de P.
1973. In R. H. Gast and A. C. Conrad, *Don Francisco de Paula Marin*. Honolulu: Univ. Press Hawaii.

Marshall, B. A.
1977. The Dextral Triforid Genus *Metaxia* (Mollusca: Gastropoda) in the South-west Pacific. *New Zealand J. Zoology* 4:111-117.

Martens, E. von
1880. *Mollusken, Beiträge zur meeresfauna der Insel Mauritius und der Seychellen*. Berlin.
1894. In Semon, *Zoologische Forschungsreisen in Australien und dem Malayischen Archipel* 5, *Mollusken*.

Martens, E. von, and B. Langkavel
1871. *Donum Bismarckianum. Eine sammlung von Sudsee Conchylien*. Berlin.

Martyn, T.
1784-1787. *The Universal Conchologist, Exhibiting the Figure of Every Known Shell . . . Drawn . . . and Painted . . . with a New Systematic Arrangement*. London. 4 vols.

Matheson, C.
1966. G. B. Sowerby the First and His Correspondents: Part II. *J. Soc. Bibliography Natural History* 4:253-266.

Mathison, G. F.
1825. *Narrative of a Voyage to Brazil, Chile, Peru and the Sandwich Islands During the Years 1821 and 1822*. London.

Mayor, R.
1975. Food Preference of a Captive *Murex insularum*. *Hawaiian Shell News* 22(8):3.

Meares, J.
1790. *Voyages Made in the Years 1788 and 1789, from China to the Northwest Coast of America*. London: Logographic Press.

Melvill, J. C.
1883. Description of a New Species of *Cassis*. *J. Conchology* 4:43-44.
1888. A Survey of the Genus *Cypraea* (Linn.): Its Nomenclature, Geographical Distribution, and Distinctive Affinities, with Descriptions of Two New Species, and Several Varieties. *Mem. Proc. Manchester Literary and Philosophical Soc.* 1:184-252.
1891. An Historical Account of the Genus *Latirus* (Montfort) and Its Dependencies, with Descriptions of Eleven New Species, and a Catalogue of *Latirus* and *Peristernia*. *Mem. Proc. Manchester Literary and Philosophical Soc.* 4:1-47.

Melvill, J. C. (cont.)

1896. Descriptions of New Species of Minute Marine Shells from Bombay. *Proc. Malacological Soc. London* 2:108-116.

1898. A Brief Bibliographical Résumé of the Erythraean Molluscan Fauna with Descriptions of Sixteen New Species from Aden. *Ann. Mag. Natural History* (Ser. 7) 1(3):194-206.

1899. Description of a New Species of *Mitra (M. baldwinii)* from the Hawaiian Islands. *J. Malacology* 7(3):67-68.

1909. Report on the Marine Mollusca Obtained by Mr. J. Stanley Gardiner, F. R. S., Among the Islands of the Indian Ocean in 1905. *Trans. Linnaean Soc. London* 13:65-138.

1917. A Revision of the Turridae (Pleurotomidae) Occurring in the Persian Gulf, Evidenced Mostly Through the Results of Dredgings Carried out by Mr. F. W. Townsend, 1893-1914. *Proc. Malacological Soc. London* 12:140-201.

1918. Descriptions of Thirty-four Species of Marine Mollusca from the Persian Gulf, Gulf of Oman and Arabian Sea, Collected by Mr. F. W. Townsend. *Ann. Mag. Natural History, London,* (Ser. 9) pp. 137-158.

Melvill, J. C., and R. Standen

1895-1897. Notes on a Collection of Shells from Lifu and Uvea, Loyalty Islands, Formed by the Rev. James and Mrs. Hadfield, with List of Species. *J. Conchology* 8:84-132; 273-315.

1898. The Marine Mollusca of Madras and the Immediate Neighborhood. *J. Conchology* 9:30-48; 75-85.

1899. Report on Marine Mollusca of the Torres Straits. *J. Linnaean Soc.* (Zool.), 27:150-206.

1901. Mollusca of the Persian Gulf, Gulf of Oman, and Arabian Sea, as Evidenced Mainly Through the Collections of Mr. F. W. Townsend, 1893-1900; with Descriptions of New Species. *Proc. Zoological Soc. London* 11:327-460.

1903. Descriptions of Sixty-eight new Gastropoda from the Persian Gulf, Gulf of Oman, and North Arabian Sea, Dredged by Mr. F. W. Townsend, of the Indo-European Telegraph Service, 1901-1903. *Ann. Mag. Natural History* 12:289-324.

Menard, H. W., E. C. Allison, and J. W. Durham

1962. A Drowned Miocene Terrace in the Hawaiian Islands. *Science* 138:896-897.

Menard, H. W., and E. L. Hamilton

1963. Paleogeography of the Tropical Pacific. In J. L. Gressitt (ed.), *Pacific Basin Biogeography: A Symposium.* Honolulu: Bishop Museum Press.

Menke, K. T.

1829. *Verzeichniss der ansehnlichen Conchylien-Sammlung des Freiherrn von den Malsburg.* Pyrmont (Germany).

1843. *Molluscorum Novae Hollandiae Specimen. . . .* Hanover.

1853. Kritische Anzeige. *Z. Malakozoologie* 10(8):113-117.

Menzies, A.

1920. *Hawaii Nei 128 Years Ago.* W. F. Wilson (ed.). Honolulu.

Michaud, A. L. G.

1830. Descriptions de plusieurs nouvelles espèces de coquilles du genre Rissoa. *Ann. Soc. Linnaean Lyons* 1.

Mighels, J. W.

1845. Descriptions of Shells from the Sandwich Islands and Other Localities. *Proc. Boston Soc. Natural History* 2:18-25.

Miller, A. C.

1970. Observations on the Distribution and Feeding of *Morula uva* (Bolten) and *Morula granulata* (Duclos) (Gastropoda: Thaisidae) in Hawaii. Abstr. in *The Biology of Molluscs,* Univ. Hawaii, Hawaii Inst. Marine Biology, Tech. Rep. 18, p. 17.

Miller, B. A.

1966. Studies on the Biology and Ecology of Some Indo-Pacific *Terebra* from Eniwetok Atoll. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.

1970. Studies on the Biology of Indo-Pacific Terebridae. Ph.D. Dissertation, Univ. New Hampshire.

1975. The Biology of *Terebra gouldi* Deshayes, 1859, and a Discussion of Life History Similarities Among Other Terebrids of Similar Proboscis Types. *Pacific Science* 29(3):227-241.

Miller, B. A., and R. A. Coker
1972. Distribution and Abundance of an Isolated Population of *Terebra gouldi* (Gastropoda: Terebridae) on a Hawaiian Subtidal Sand Flat. *Ecology* 53(6):1120-1126.

Miller, R. C.
1924. Wood-boring Mollusks from the Hawaiian, Samoan, and Philippine Islands. *Univ. California Publ. Zoology* 26(7):145-151.

Montfort, P. D. de
1808-1810. *Conchyliologie systématique et classification méthodique de coquilles. . . .* Paris.

Montrouzier, Le R. P.
1861. In M. Souverbie, Descriptions de'espèces nouvelles de l'Archipel Calédonien. *J. Conchyliologie* 9:271-284.
1864. (With M. Souverbie). Descriptions d'espèces nouvelles de l'Archipel Calédonien. *J. Conchyliologie* 12:261-275.

Mörch, D. A. L.
1861. Review of the Vermetidae. Part I. *Proc. Zoological Soc. London*, pp. 145-181.
1863a. Contributions à la Faune malacologique des Antilles danoises. *J. Conchyliologie* 11:21-43.
1863b. Révision des Espèces du genre *Oxynoe* et *Lobiger*. *J. Conchyliologie* 11:43-48.

Morris, P. A.
1952. *A Field Guide to Shells of the Pacific Coast and Hawaii*. Boston: Houghton Mifflin.
1966. *A Field Guide to Shells of the Pacific Coast and Hawaii*. (2nd ed.) Boston: Houghton Mifflin.

Morrison, J. P. E.
1954a. The Relationships of Old and New World Melanians. *Proc. United States Nat. Mus.* 103:357-394.
1954b. Animal Ecology of Raroia Atoll, Tuamotus. I. Ecological Notes on the Mollusks and Other Animals of Raroia. *Atoll Research Bull.* No. 34, pp. 1-28.
1965. Notes on the Genera of Hipponicidae. *Ann. Rep. American Malacological Union for 1965*, pp. 33-34.

Morton, J.
1967. *Molluscs*. London: Hutchinson Univ. Library.

Morton, J., and M. Miller
1968. *The New Zealand Seashore*. London, Auckland: Collins.

Mühlfeld, J. K. Megerle von
1811. Entwurf eines Neuen Systems der Schaltiergehäuse. *Magazin für die neusten Entdecklungen in der gesammten Naturkunde Der gesell. Naturforsch Fr. zu Berlin* 5:38-72.

Müller, O. F.
1776. *Zoologie Danicae prodromus seu Animalium Daniae et Norvegiae indigenarum characters nomina et synonym imprimus pularium*. 8 vols.

Nevill, G.
1885. *Hand List of Mollusca in the Indian Museum, Calcutta*. Part II. *Gastropoda. Prosobranchia – Neurobranchia*. Calcutta.

Newcomb, W.
1870. Descriptions of New Species of Marine Mollusca. *American J. Conchology*, 5:163-164.

Nicol, D.
1956. Distribution of Living Glycymerids with a New Species from Bermuda. *Nautilus* 70(2):48-53.

Nomura, S., and K. Hatai
1940. The Marine Fauna of Kyuroku-sima and Its Vicinity, Northeast Honshyu, Japan. *Saito Hoon Kai Museum Research Bull.* 19:57-115.

O'Brien, A.
1966. HMS Fossil Trip to Kahi Point. *Hawaiian Shell News* 14(7):1.

O'Donoghue, C. H.
1930. Opisthobranchiate Mollusca collected by the South African Marine Biological Survey. *Rep. Fisheries Marine Biological Survey South Africa* 7:1-84.

Okutani, T.
1963. Preliminary Notes on Molluscan Assemblages of the Submarine Banks Around the Izu Islands. *Pacific Science* 17(1):73-89.

Okutani, T. (cont.)
1975. Glimpse of Benthic Molluscan Fauna Occupying the Submarine Bank, Kurose, Near Hachijo Island, Japan. *Venus* 33(4):185-205.

Old, W., Jr.
1963. *Cypraea latior* Melvill, 1881. *Hawaiian Shell News* 12(2):4.

Oliver, W. R. B.
1915 (1914). The Mollusca of the Kermadec Islands. *Trans. New Zealand Inst.* 47:509-568.

Olsson, A. A. I.
1961. *Mollusks of the Tropical Eastern Pacific. Panamic-Pacific Pelecypoda.* Paleontological Research Inst., Ithaca, New York.

Orbigny, A. d'
1834-1847. *Voyage dans l'Amérique Méridionale Mollusques.* Paris.

Orr, V.
1962. The Drilling Habit of *Capulus danieli* (Crosse) (Mollusca: Gastropoda). *Veliger* 5:63-67.
1966. Sexual Dimorphism in the Radula of the Muricid Genus *Nassa*. *Nautilus* 79(3):73-80.

Ostergaard, J. M.
1920. A New *Cypraea* from Hawaii. *Nautilus* 33:92.
1928. *Fossil Marine Mollusks of Oahu.* B. P. Bishop Mus. Bull. 51, 32 pp.
1937. Distribution of Fossil Oysters in Hawaii. *Nautilus* 50(3):88-89.
1939. Reports on Fossil Mollusca of Molokai and Maui *B. P. Bishop Mus. Occ. Pap.* 15(6):67-77.
1950. Spawning and Development of Some Hawaiian Marine Gastropods. *Pacific Science* 4:75-115.
1955. Some Opisthobranch Mollusca from Hawaii. *Pacific Science* 9:110-136.
1960. Distribution of *Strombus ostergaardi* Pilsbry. *Hawaiian Shell News* 8(7):3.

Pace, S.
1901. Rediscovery of *Euselenops (=Neda) luniceps* (Cuv). *Proc. Malacological Soc. London* 4:202-204.
1902. Contributions to the Study of the Columbellidae: No. 1. *Proc. Malacological Soc. London* 5:36-154.

Paetel, Fr.
1873. *Catalog der Conchylien-Sammlung.* Berlin.

Palmer, C. P.
1974. A Supraspecific Classification of the Scaphopod Mollusca. *Veliger* 17(2):115-123.

Pearson, R. J., P. V. Kirch, and M. Pietrusewsky
1971. An Early Prehistoric Site at Bellows Beach, Waimanalo, Oahu, Hawaiian Islands. *Archaeology and Physical Anthropology in Oceania* 6(3):204-234.

Pease, W. H.
1860. Descriptions of New Species of Mollusca from the Sandwich Islands, Part I, II. *Proc. Zoological Soc. London,* pp. 18-36; 141-148.
1861a. (1860). Descriptions of Seventeen New Species of Marine Shells from the Sandwich Islands, in the Collection of Hugh Cuming. *Proc. Zoological Soc. London,* pp. 397-400.
1861b (1860). Descriptions of Forty-seven New Species of Shells, from the Sandwich Islands, in the Collection of Hugh Cuming. *Proc. Zoological Soc. London,* pp. 431-438.
1861c. Descriptions of New Species of Mollusca from the Pacific Islands. *Proc. Zoological Soc. London,* pp. 242-247.
1862. Catalogue des espèces de *Rissoina* des Îles Sandwich et description d'une espèce nouvelle. *J. Conchyliologie* 10:381-383.
1863a (1862). Descriptions of New Species of Marine Shells from the Pacific Islands (sic). *Proc. Zoological Soc. London,* pp. 240-243.
1863b (1862). Descriptions of New Species of Shells from the Pacific Islands. *Proc. Zoological Soc. London,* pp. 243-245.
1863c. (1862). Descriptions of New Species of Marine Shells from the Pacific Islands. *Proc. Zoological Soc. London,* pp. 278-280.
1864 (1863). On Errors and Omissions in Former Communications. *Proc. Zoological Soc. London,* p. 510.
1865a (1864). Descriptions of New Species of Land Shells from the Islands of the Central Pacific. *Proc Zoological Soc. London,* pp. 668-676.

Pease, W. H. (cont.)
1865b. Descriptions of New Genera and Species of Marine Shells from the Islands of the Central Pacific. *Proc. Zoological Soc. London*, pp. 512-517.
1866. Remarks on Nudibranchiata Inhabiting the Pacific Islands, with Descriptions of Two New Genera. *American J. Conchology* 2:204-208.
1868a. Descriptions of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 3(3):211-222.
1868b. Descriptions of Sixty-five New Species of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 3:271-297.
1868c. Descriptions of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 4:71-80.
1868d. Descriptions of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 4:91-102.
1868e. Synonymy of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 4:103-132.
1869a. Letter to Andrew Garrett. Oct. 1869. B. P. Bishop Museum. MS. collection.
1869b. Descriptions of New Species of Marine Gasteropodae Inhabiting Polynesia. *American J. Conchology* 5:64-79.
1871a (1870). Remarks on the Genus *Triphoris* (Desh.) with Descriptions on New Species. *Proc. Zoological Soc. London*, pp. 773-777.
1871b. Descriptions of Nudibranchiate Mollusca, Inhabiting Polynesia. *American J. Conchology* 6:299-305.
1871c. Descriptions of New Species of Nudibranchiate Mollusca Inhabiting Polynesia, No. 2. *American J. Conchology* 7:11-19.
1871d. Notes on the Synonymy and Distribution of Marine Gasteropoda. *American J. Conchology* 7:20-25.
1872. Polynesian Chitonidae. *American J. Conchology* 7:194-195.

Pelseneer, P.
1888. Report on the Pteropoda Collected by H. M. S. Challenger During the Years 1873-1876. Part II. The Thecosomata. *Rep. Scientific Results Voyage H. M. S.* Challenger, *Zoology 23*. Edinburgh.

Perron, F.
1975. Carnivorous *Calliostoma* (Prosobranchia: Trochidae) from the Northeastern Pacific. *Veliger* 18(1):52-56.

Perry, G.
1811. *Conchology: Or the Natural History of Shells*. London.

Petit, M. S. de la S.
1851a. Notice sur le genre *Stylifer* Brod., et description d'une espèce nouvelle. *J. Conchyliologie* 2:25-29.
1851b. Description de coquilles nouvelles. *J. Conchyliologie* 2:365-368.
1853. Description de coquilles nouvelles. *J. Conchyliologie* 4:360-369.

Pfeffer, G.
1912. Die Cephalopoden der Plankton-Expedition. *Ergebenisse der Plankton-Expedition der Humboldt-Stiftung*, Vol. 2, 185 pp.

Pfeiffer, L.
1856. *Monographia Auriculaceorum viventium*. Cassel: Fischer.

Philippi, R. A.
1842-1851. *Abbildungen und Beschreibungen never oder wenig gekannter Conchylien*. 3 vols. Cassel.
1846a. Diagnoses testaceorum quorundam novarum. *Z. Malakozoologie*, pp. 47-105.
1846b (1845). Descriptions of a New Species of *Trochus*, and of Eighteen New Species of *Littorina*, in the Collection of H. Cuming, Esq. *Proc. Zoological Soc. London*, pp. 138-143.
1847. Diagnoses testaceorum quorundam novarum. *Z. Malakozoologie*, pp. 97-106.
1852. *Systematisches Conchylien-Cabinet* (ed. 2). *Die Gattungen Natica und Amaura*. Nürnberg.

Pilsbry, H. A.
1888-1898. In G. W. Tryon, *Manual of Conchology*. Vol. 10, 1888; 11, 1889; 12, 1890; 13, 1891; 14, 1892; 15, 1893; 16, 1895-96; 17, 1897-98. Philadelphia.

Pilsbry, H. A. (cont.)

1917-1921. Marine Mollusks of Hawaii. *Proc. Acad. Natural Sciences Philadelphia*, Vols. 1-3, 1917 (1916), 69:207-230; 219-230; 4-6, 1918 (1917), 69:309-333; 8-13, 72:296-328; 14, 15, 1921 (1920), 72:360-382.

1936. *Ostrea kamehameha*. *Nautilus* 49:103-104.

1944. Hawaiian Species of *Odostomia Nautilus* 58(2):64-65, [*Odostomia monaulax*, *Nautilus* 58:106; *Odostomia hiloensis*, *Nautilus* 58: Pl. 6, f. 5 (1945)].

Pilsbry, H. A., and E. L. Bryan

1918. Notes on Some Hawaiian Species of *Drupa* and Other Shells. *Nautilus* 31:99-102.

Pilsbry, H. A., and C. M. Cooke

1912-1920. In G. W. Tryon, *Manual of Conchology*, Vol. 22 (1912-1914), Vol. 23 (1914-1916), Vol. 25 (1920). Philadelphia.

Pilsbry, H. A., and T. L. McGinty

1945. Cyclostrematidae and Vitrinellidae of Florida—II. *Nautilus* 59:52-59.

Pilsbry, H. A., and A. A. Olsson

1952. Vitrinellidae of the Panamic Province. II. *Proc. Acad. Natural Sciences Philadelphia* 104:38-88.

Pilsbry, H. A., and E. G. Vanatta

1905. On Two Hawaiian Cerithiidae. *Proc. Acad. Natural Sciences Philadelphia* 57(195):576.

1908. Descriptions of New Hawaiian Marine Shells. *Nautilus* 22(6):56-58.

Pollock, J. B.

1928. *Fringing and Fossil Coral Reefs of Oahu*. B. P. Bishop Mus. Bull. 55, 56 pp.

Ponder, W. F.

1965a. The Family Eatoniellidae in New Zealand. *Rec. Auckland Inst. Mus.* 6:47-99.

1965b. A Revision of the New Zealand Recent Species Previously Known as Notosetia Iredale, 1915 (Rissoidae, Gastropoda). *Rec. Auckland Inst. Mus.* 6:101-131.

1966a. The New Zealand Species Previously Known as *Zelaxitas* Finlay, 1927 (Mollusca, Gastropoda). *Rec. Dominion Mus.* 5:163-176.

1966b. A New Family of the Rissoacea from New Zealand. *Rec. Dominion Mus.* 5:177-184.

1967. The Classification of the Rissoidae and Orbitestellidae with Descriptions of Some New Taxa. *Trans. Royal Soc. New Zealand, Zoology* 9:193-224.

1970. Some Aspects of the Morphology of Four Species of the Neogastropod Family Marginellidae with a Discussion of the Evolution of the Toxoglossan Poison Gland. *J. Malacological Soc. Australia* 2(1):55-81.

1971. Some New Zealand and Subantarctic Bivalves of the Cyamiacea and Leptonacea with Descriptions of New Taxa. *Rec. Dominion Mus.* 7:119-141.

1972a. The Morphology of Some Mitriform Gastropods with Special Reference to their Alimentary and Reproductive Systems. (Neogastropoda). *Malacologia* 11:295-342.

1972b. Notes on Some Australian Genera and Species of the Family Muricidae (Neogastropoda). *J. Malacological Soc. Australia* 2:215-248.

1972c. Notes on Some Australian Species and Genera of the Family Buccinidae (Neogastropoda). *J. Malacological Soc. Australia* 2:249-265.

1973. The Origin and Evolution of the Neogastropoda. *Malacologia* 12:295-338.

Ponder, W. F., and R. V. Gooding

1979 (1978). Four New Eulimid Gastropods Associated with Shallow-water Diademnatid Echinoids in the Western Pacific. *Pacific Science* 32(2):157-181.

Ponder, W. F., and E. K. Yoo

1977. A Revision of the Australian Species of the Rissoellidae. (Mollusca: Gastropoda). *Rec. Australian Museum* 31:133-185.

Poulter, J. L.

1963. The Taxonomy and Anatomy of Some of the Common Polyclad Flatworms of Oahu with Notes on their Biology. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.

Powell, A. W. B.

1930. New Species of New Zealand Mollusca from Shallow-water Dredgings. *Trans New Zealand Inst.* 60:532-543.

Powell, A. W. B. (cont.)
1935. Marine Mollusca from the Bounty Islands. *Rec. Canterbury Mus.* 4:29-39.
1961. Mollusca from the Kermadec Islands, a marginal Indo-Pacific area. *Proc. Ninth Pacific Science Congr.* (1957) 10:8.
1964. The Family Turridae in the Indo-Pacific. Part I. The Subfamily Turrinae. *Indo-Pacific Mollusca* 1(5):227-345.
1966. *The Molluscan Families Speightiidae and Turridae.* Auckland Inst. Mus. Bull. 5, 184 pp.
1967. The Family Turridae in the Indo-Pacific. Part 1a. The Family Turrinae Concluded. *Indo-Pacific Mollusca* 1(7):409-443.
1969. The Family Turridae in the Indo-Pacific. Part 2. The Subfamily Turriculinae. *Indo-Pacific Mollusca* 2(10):215-415.
1973. The Patellid Limpets of the World (Patellidae). *Indo-Pacific Mollusca* 3(15):75-206.

Powys, W. L.
1835. Undescribed Shells Contained in Mr. Cuming's Collection . . . Accompanied by Characters by Mr. G. B. Sowerby and Mr. W. Lytellton Powys. *Proc. Zoological Soc. London*, pp. 93-96.

Prashad, B.
1932. The Lamellibranchia of the Siboga Expedition. Systematic part II. Pelecypoda exclusive of the Pectinidae. *Siboga-Expeditie* 3:1-353.

Preston, H. B.
1904. Descriptions of Some New Species of Cingalese and Indian Marine Shells. *J. Malacology* 11:75-78.
1905. Descriptions of New Species of Marine Shells from Ceylon. *J. Malcology* 12:1-8.
1908. Descriptions of New Species of Land, Marine, and Freshwater Shells from the Andaman Islands. *Rec. Indian Mus.* 2(2):187-210.

Purtyman, B.
1974. Oahu Observations. *Hawaiian Shell News* 22(2):4.

Quatrefages, A. de
1849. Mémoire sur le genre Taret (*Teredo* Linn). *Ann. Science Naturelle Zoologie* (Paris) 11(3):19-64.

Quoy, J. R. C., and J. P. Gaimard
1824-1826. In L. de Freycinet *Voyage autour du monde . . . pendant . . . 1817-1820. . . . Uranie et Physicienne . . . Zoologie*, Paris.
1832-1835. *Voyage de découvertes de L'Astrolabe exécuté par ordre du Roi, pendant les années 1826-1828-1829, sous le commandement de M. J. Dumont d'Urville. Zoologie. Mollusca.* Paris, Vol. 2, Pt 2, pp. 321-686.

Radwin, G. E., and A. D'Attilio
1976. *Murex Shells of the World.* California: Stanford University Press.

Rang, S.
1828. Histoire naturelle des Aplysiens, première famille de l'ordre des Tectibranches. In Férussac, *Histoire naturelle géneral et particulaire des mollusques.* Paris, 1827, pp. 1-84.

Ranson, G.
1961. Les espèces d'huitres perlieres du genre *Pinctada* (biologie de quelques-unes d'entre elles). *Mem. Inst. Science Naturelle Belgique* 67(2):1-95.

Recluz, C. A.
1841. Description de quelques nouvelles espèces de Nérites vivantes. *Rev. Zoological Soc. Cuvierienne* 4:102-109.
1844. Descriptions of New Species of *Navicella, Neritina, Nerita,* and *Natica* in the Cabinet of H. Cuming, Esq. *Proc. Zool. Soc. London,* Pt. 11, pp. 197-214.

Redfield, J. H.
1869. Catalogue of the Known Species, Recent and Fossil, of the Family Marginellidae. Appendix, *American J. Conchology* 5:214-325.

Reeve, L.
1842. Monograph of the Genus *Tornatella,* a Small Group of Pectinibranchiate Mollusks of the Family Plicacea, Including Descriptions of Several New Species. *Proc. Zoological Soc. London,* pp. 58-62.

Reeve, L. (cont.)
1843-1878. *Conchologia iconica: Or, Illustrations of the Shells of Molluscous Animals*. London: Reeve Brothers, Vols. 1-15 by Reeve; Vols. 16-20 by Sowerby. 20 vols.

Rehder, H. A.
1943. New Marine Mollusks from the Antillean Region. *Proc. U. S. National Mus.* 93(3161):187-203.
1964. Notes on Hawaiian Muricidae. *Hawaiian Shell News* 12(6):4-5.
1973. The Family Harpidae of the World. *Indo-Pacific Mollusca* 3(16):207-272.

Rehder, H. A., and H. S. Ladd
1973. Deep and Shallow-water Mollusks from the Central Pacific. *Scientific Rep. Tohoku Univ.* (2nd Ser.) 6:37-49.

Rehder, H. A., and J. E. Randall
1975. Ducie Atoll: Its History, Physiography and Biota. *Atoll Res. Bull.* 183. 40 pp.

Resig. J. M.
1969. *Paleontological Investigations of Deep Borings on Ewa Plain, Oahu, Hawaii*. HIG-69-2. Univ. Hawaii, Hawaii Inst. Geophysics.

Rigacci, G., and E. Rigacci
1866. *Catalogo delle conchiglie componenti la collezione Regacci*. Rome.

Rippingale, O. H., and D. F. McMichael
1961. *Queensland and Great Barrier Reef Shells*. Brisbane: Jacaranda Press.

Risbec, J.
1928. Contribution a l'etude des Nudibranches New Caledoniens. *Faune Colonies Française* 2(1):1-328.
1929. Notes zoologiques et anatomiques sur quelques opisthobranches de Madagascar. Mollusca 1. Opisthobranchia. *Faune Colonies Française* 3:45-62.
1953. Mollusques nudibranches de la nouvelle-Calédonie. *Faune Union Française Paris* 15:1-189.
1955. Considerations sur l'anatomie comparée et la classification des gastéropodes Prosobranches. *J. Conchyliologie* 95:45-82.
1956. Nudibranchs du Viet-Nam. *Archiv. Mus. National d'Histoire Naturelle* (Paris) (Ser. 7) 4:1-34.

Roberts, S. R.
1868. Description of a New Species of *Cypraea*. *American J. Conchology* 4(2):70.
1869. Descriptions of Two New *Cypraea*. *American J. Conchology* 4:250-251.

Robertson, R.
1961. A Second Western Atlantic *Rissoella* and a List of the Species in the Rissoellidae. *Nautilus* 74:131-136; 75:21-26.
1963. Wentletraps (Epitoniidae) Feeding on Sea Anemones and Corals. *Proc. Malacological Soc. London* 35(2, 3):51-63.
1964. Dispersal and Wastage of Larval *Philippia krebsii* (Gastropoda: Architectonicidae) in the North Atlantic. *Proc. Acad. Natural Sciences Philadelphia* 116:1-27.
1970a. Review of the Predators and Parasites of Stony Corals, with Special Reference to Symbiotic Prosobranch Gastropods. *Pacific Science* 24:43-54.
1970b. Systematics of Indo-Pacific *Philippia (Psilaxis)*, Architectonicid Gastropods with Eggs and Young in the Umbilicus. *Pacific Science* 24:66-83.
1971. Sexually Dimorphic Archaeo-gastropods and Radulae. *Ann. Rep. for 1970. American Malacological Union*, pp. 75-78.
1976. *Heliacus trochoides:* An Indo-West Pacific Architectonicid Newly Found in the Eastern Pacific (Mainland Ecuador). *Veliger* 19(1):13-16.

Robertson, R., R. S. Scheltema, and F. W. Adams
1970. The Feeding, Larval Dispersal and Metamorphosis of *Philippia* (Gastropoda: Architectonicidae). *Pacific Science* 24:55-65.

Röding, P. F.
1798. *Museum Boltenianum sie Catalogus Cimeliorum, pars secunda Conchylia*. Hamburg: Trappii.

Roper, C. F. E., and R. E. Young
1975. *Vertical Distribution of Pelagic Cephalopods*. Smithsonian Contrib. Zoology 209.

Rosewater, J.
1961. The Family Pinnidae in the Indo-Pacific. *Indo-Pacific Mollusca* 1(4):175-226.
1970. The Family Littorinidae in the Indo-Pacific. Part I. The Family Littorininae. *Indo-Pacific Mollusca* 2(11):417-506.

Rosin, R.
1969. Escape Response of the Sea-anemone *Anthopleura nigrescens* (Verrill) to its Predatory Eolid Nudibranch *Herviella* Baba spec. nov. *Veliger* 12(1):74-77.

Rothschild, W.
1893-1900. *The Avifauna of Laysan and Neighbouring Islands*. London: Porter.

Rudman, W. B.
1971. On the Opisthobranch Genus *Haminoea* Turton and Kingston. *Pacific Science* 25(4):545-559.
1972a. Structure and Functioning of the Gut in the Bullomorpha (Opisthobranchia). Part 2. Acteonidae. *J. Natural History* 6(3):311-324.
1972b. Studies on the Primitive Opisthobranch Genera *Bullina* Férussac and *Micromelo* Pilsbry. *Zoological J. Linnaean Soc.* 51:105-119.
1972c. The Anatomy of the Opisthobranch Genus *Hydatina* and the Functioning of the Mantle and Alimentary Canal. *Zoological J. Linnaean Soc.* 51(2):121-139.
1972d. A Comparative Study of the Genus *Philinopsis* Pease, 1860 (Aglajidae, Opisthobranchia). *Pacific Science* 26(4):381-399.
1972e. The Herbivorous Opisthobranch Genera *Phanerophthalmus* A. Adams and *Smaragdinella* A. Adams. *Proc. Malacological Soc. London* 40:189-210.
1973. Chromodorid Opisthobranch Mollusca from the Indo-West Pacific. *Zoological J. Linnaean Soc.* 52(3):175-199.
1977. Chromodorid Opisthobranch Mollusca from East Africa and the Tropical West Pacific. *Zoological J. Linnaean Soc.* 61(4):351-397.
1978. The Dorid Opisthobranch Genera *Halgerda* Bergh and *Sclerodoris* Eliot from the Indo-West Pacific. *Zoological J. Linnaean Soc.* 62:59-88.

Rüppell, W. P. E. S., and F. S. Leuckart
1831. Mollusca. In *Atlas zu der Reise im nordlichen Afrika von Eduard Rüppell*. Frankfurt.

Sacco, F.
1904. *I Molluschi dei Terreni terziarii del Piemonte e della Liguria*. Pt. XXX (Aggiunte e Correzioni). Turin.

Safriel, U.
1966. Recent Vermetid Formation on the Mediterranean Shore of Israel. *Proc. Malacological Soc. London* 37:27-34.

Saito, Y., and N. Nakamura
1961. Biology of the Sea Hare, *Aplysia juliana* as a Predator of the Brown Seaweed, *Undaria pinnatifida*. I. The Feeding Habit. *Bull. Japanese Soc. Scientific Fisheries* 27:395-400.

Sakurai, K., and T. Habe
1973. Family Mesodesmatidae of Japan and Adjacent Area with the Description of a New Species. *Venus* 32(1):4-8.

Salis Marschlins, C. U. von
1793. *Reisen in verschiedenen Provinzen des Königsreichs Neapel*. Zurich and Leipzig: Ziegler.

Salisbury, R.
1978. Hawaii's Fifty-odd *Terebra*. *Hawaiian Shell News* 26(8):7-10.

Sander, K.
1950. Beobachtungen zur Fortpflanzung von *Assiminea grayana* Leach. *Archiv. Molluskenkunde* 79:147-149.

Sarasin, P., and F. Sarasin
1887. Ueber zwei parasitische schnecken. *Erg. Naturw. Forsch. Ceylon, 1884-1886* 1(1):19-32.

Sarver, D.
1977. The Ecology and Energetics of *Aplysia juliana* (Quog and Gaimard, 1832). Ph.D. Dissertation, Univ. Hawaii, Honolulu, Hawaii.

Satyamurti, S. T.
1946. A New Pleurobranch from Pamban, South India. *Proc. Malacological Soc. London* 27:76-83.

Scheltema, A. H.
1978. Position of the Class Aplacophora in the Phylum Mollusca. *Malacologia* 17(1):99-109.

Scheltema, R.
1971. Larval Dispersal as a Means of Genetic Exchange Between Geographically Separated Populations of Shallow-water Benthic Marine Gastropods. *Biological Bull.* 140(2):284-322.

Schepman, M. M.
1908-1913. *The Prosobranchia of the Siboga Expedition: Resultats Siboga Expeditie.* Mon. 49-1, Pt. 1 (1908), Pt. 2 (1909), Pt. 3 (1909), Pt. 4 (1911), Pt. 5 (1913).

Schilder, F. A.
1927. Revision der Cypraeacea. *Archiv Naturgeschicte* A(10):1-165.
1932. Cypraeacea. In *Fossilium Catalogus* I, 55. 276 pp.
1933. Cypraeacea from Hawaii. *B. P. Bishop Mus. Occ. Pap.* 10(3):1-22.
1962. Zur kenntnis der Cypraeidae. Eine neue Riesenform aus Ostafrika. *Archiv Molluskenkunde* 91:207-212.
1965. *Cypraea maculifera* from the Seychelles. *Hawaiian Shell News* 13(11):6.

Schilder, F. A., and M. Schilder
1938-1939. Prodrome of a Monograph on Living Cypraeidae. *Proc. Malacological Soc. London* 23(3):119-180; 23(4):181-231.

Schröter, J. S.
1804. Neue Conchylienarten und Abänderungen, Anmerkungen und Berichtigungen nach dem Linneischen Systems der XII Ausgabe (Fortsetzung). *Archiv Zoologisch Zootomie* 4(1):7-44.

Schubert, H. G., and J. A. Wagner
1829. *Neues systematisches Conchylien-Cabinet angefangen von Martini und Chemnitz, fortgesetzt von G. H. Schubert und J. A. Wagner.* Nürnberg, 12.

Schultz
1836. In Philippi, R. A., *Enumeratio molluscorum Sicilae cum viventium tum in tellure tertiaria fossilium quae in itinere suo observavit* 1. Berolini.

Schumacher, C. F.
1817. *Essai d'un nouveau système des habitations des vers testacés.* Copenhagen. 287 p.

Sharp, D., Editor
1899-1913. *Fauna Hawaiiensis; Being the Land Fauna of the Hawaiian Islands. . . .* 3 vols. Cambridge: Cambridge Univ. Press.

Shasky, D. R.
1971. Ten New Species of Tropical Eastern Pacific Turridae. *Veliger* 14:67-72.

Shaw, H. O. N.
1909. Notes on the Genera *Cypraea* and *Trivia. Proc. Malacological Soc. London* 8:308-313.

Shikama, T.
1970. On Some Noteworthy Marine Gastropoda from Southwestern Japan. *Scientific Rep. Yokohama National Univ.* (Sect. 2) 16:19-27.

Sinoto, Y. H.
1967. Artifacts from Excavated Sites in the Hawaiian, Marquesas, and Society Islands. In G. Highland and others (eds.), *Polynesian Culture History.* B. P. Bishop Mus. Spec. Publ. 56. Honolulu: Bishop Mus. Press.

Slvickis, P. B.
1928. New Philippine Shipworms. *Philippine J. Science* 37:285-298.

Smith, E. A.
1872. A List of the Genus *Planaxis,* with Descriptions of Eleven New Species. *Ann. Mag. Natural History* (Ser. 4) 9:37-47.
1873. Remarks on a Few Species Belonging to the Family Terebridae, and Descriptions of Several New Forms in the Collection of the British Museum. *Ann. Mag. Natural History* (Ser 4) 11:262-271.
1876. A List of Marine Shells, Chiefly from the Solomon Islands, with Descriptions of Several New Species. *J. Linnaean Soc. London Zoology* 12:535-562.
1877. Diagnoses of New Species of Pleurotomidae in the British Museum. *Ann. Mag. Natural History* (Ser. 4) 19:488-501.
1878. On a Collection of Marine Shells from the Andaman Islands. *Proc. Zoological Soc. London,* pp. 804-821.
1879. On a Collection of Mollusca from Japan. *Proc. Zoological Soc. London,* pp. 181-218.

Smith, E. A. (cont.)
1884. Mollusca. In British Museum (Natural History) Dept. of Zoology. *Report on the Zoological Collections Made in the Indo-Pacific Ocean during the Voyage of H.M.S.* Alert 1881-1882. London.
1885. Report on the Lamellibranchiata. *Rep. Scientific Results Voyage H.M.S.* Challenger, Zoology. Vol. 13.
1901. On South African Marine Shells, with Descriptions of New Species. *J. Conchology* 10:104-116.
1904. Description of a New Species of *Cassis*. *Proc. Malacological Soc. London* 6:21-22.
1906. Mollusca. In *The History of the Collections Contained in the Natural History Departments of the British Museum, London*. Vol. 2.
1908. On the Known Recent Species of the Genus *Vanikoro*, Quoy and Gaimard. *Proc. Malacological Soc. London* 5(6):354-402.
1909. List of Mollusca from Christmas Island, Indian Ocean. *Proc. Malacological Soc. London* 8:369-372.
1910. On South African Marine Mollusca, with Descriptions of New Species. *Ann. Natal Mus.* 2:175-219.

Solem, G. A.
1954. Living Species of the Pelecypod Family Trapeziidae. *Proc. Malacological Soc. London* 31(2):64-84.
1974. *The Shell Makers: Introducing Mollusks*. New York: Wiley-Interscience.

Souleyet, F. L. A.
1852. Mollusques. In *Voyage autour du monde exécuté pendant . . . 1836 et 1837 sur la corvette la* Bonite *commandée par M. Vaillant. Zoologie*, Vol. 2. Paris.

Southward, A. J.
1958. The Zonation of Plants and Animals on Rocky Sea Shores. *Biological Reviews* 33:137-177.

Souverbie, M.
1875. Descriptions d'espèces nouvelles de l'Archipel Caledonien. *J. Conchyliologie* 23:282-296.
1876. Descriptions d'espèces nouvelles. *J. Conchyliologie* 16:382-383.

Sowerby, G. B. [1st of the name]
1825. *A Catalogue of the Shells Contained in the Collection of the Late Earl of Tankerville . . . with an Appendix Containing Descriptions of Many New Species*. London.
1832. Characters of New Species of Mollusca and Conchifera, Collected by Mr. Cuming. *Proc. Zoological Soc. London*, pp. 113-120; 194-202.
1833. Characters of New Species of Mollusca and Conchifera, Collected by Mr. Cuming. *Proc. Zoological Soc. London*, pp. 82-85.
1834. Characters of New Genera and Species of Mollusca and Conchifera Collected by Mr. Cuming. *Proc. Zoological Soc. London*, pp. 6-8 (Genus *Eulima*); pp. 123-128 (Genus *Fissurella*).
1839. In F. W. Beechey, *The Zoology of Capt. Beechey's Voyage . . . to the Pacific and Behring Straits . . . in . . . 1825-1828*. London.
1844. Descriptions of Some New Species of *Columbella* in the Collection of H. Cuming. *Proc. Zoological Soc. London*, pp. 45-53.

Sowerby, G. B. [2nd of the name]
1821-1834. *The Genera of Recent and Fossil Shells*. 2 vols. London.
1832-1841. *The Conchological Illustrations*. London.
1841 (1840). Descriptions of Some New Species of *Murex*, Principally from the Collection of Mr. Cuming, *Proc. Zoological Soc. London*, pp. 137-147.
1841. Descriptions of Eight New Species of the Genus *Ranella*. *Proc. Zoological Soc. London*, pp. 51-53.
1842-1887. *Thesaurus Conchyliorum: Or Monographs of Genera of Shells*. 5 vols. London.
1844. Descriptions of New Species of *Scalaria* Collected by H. Cuming to be Figured in the Fourth Part of the "*Thesaurus Conchyliorum*." *Proc. Zoological Soc. London*, pp. 10-14.
1865-1878. *Conchologia iconica: Or Illustrations of the Shells of Molluscous Animals*. Vols. 15-20. London.

Sowerby, G. B. [2nd of the name] (cont.)

1870. Descriptions of Forty-eight New Species of Shells. *Proc. Zoological Soc. London*, pp. 249-259.

1873. Description of Twelve New Species of Shells. *Proc. Zoological Soc. London*, pp. 718-722.

Sowerby, G. B. [3rd of the name]

1890. Descriptions of Fourteen New Species of Shells. *J. Linnaean Soc. London Zoology*, pp. 395-400.

1898-1904. Mollusca of South Africa. In *Marine Investigations in South Africa*. Vols. 1, 2 and 4. Cape Town.

1907. Descriptions of New Marine Mollusca from New Caledonia, etc. *Proc. Malacological Soc. London* 7:299-303.

1908a. Description of Eight New Species of Marine Mollusca. *Proc. Malacological Soc. London* 8(1):16-19.

1908b. Descriptions of New Species of *Terebra, Pleurotoma, Trochus, Tellina, Dosinia,* and *Modiola*. *Proc. Malacological Soc. London* 8:198-201.

1908c. *Mitra recurvirostris;* Name Substituted for *M. recurva* Sowerby. *Proc. Malacological Soc. London* 8:4.

1909. Descriptions of New Species of *Terebra, Pleurotoma, Trochus, Tellina, Dosinia,* and *Modiola*. *Proc. Malacological Soc. London*, pp. 198-201.

1914. Descriptions of New Species of Mollusca from New Caledonia, Japan, and Other Localities. *Proc. Malacological Soc. London* 11(1):5-10.

1915. Descriptions of New Species of Mollusca from Various Localities. *Ann. Mag. Natural History, London* 16(8):164-170.

Sowerby, J.

1812-1845. *Mineral Conchology*. Vols. 1-7. London.

Sparks, A. K.

1962. *A Preliminary Survey of the Oyster Potential of Hawaii*. Rep. Hawaii Div. Fish and Game, Bd. Agriculture Natural Resources. 76 pp.

1963. Infection of *Crassostrea virginea* (Gmelin) from Hawaii with a Larval Tapeworm, *Tylocephalum*. *J. Insect Pathology* 5(3):284-288.

Spengler, L.

1783. Beskrifoning over en ny Slaegt of toskallede Muslinger, some kan Kaldes *Gastrochaena*, i 3 forskiellige Arter. *Dansk. Selsk. Skrift N. Samml.*, pp. 174-183.

1798. Over det toskallede slaegt Tellinerne. *Skr. Naturhist. Selsk. Kobenhavn* 4(2):67-127.

Sphon, G.

1971. New Opisthobranch Records for the Eastern Pacific. *Veliger* 13(4):368.

Steadman, W. R., and B. C. Cotton

1943. The Cowries (Cypraeidae) of Fiji. *Rec. South Australian Mus.* 7:309-336.

Stearns, H. T.

1966. *Geology of the State of Hawaii*. Palo Alto: Pacific Books.

Stearns, R. E. C.

1892. In Memoriam: Dr. Wesley Newcomb. *Nautilus* 5(11):121-124.

Steenstrup, J. J. S.

1850. Beskrivelse over nogle maerkelige tildeeld nye Dyrarter. *Overs. k. Danske Vidensk. Selsk. Forh.*, pp. 55-75.

Stephenson, T. A., and A. Stephenson

1949. The Universal Features of Zonation between Tide Marks on Rocky Coasts. *J. Ecology* 37:289-305.

Stimpson, W.

1855. Descriptions of Some New Marine Invertebrata. *Proc. Acad. Natural Sciences Philadelphia* 7:385-395.

1856. Descriptions of Some New Marine Invertebrates. *Proc. Acad. Natural Sciences Philadelphia* 7:375-384.

Strauch, F.

1968. Determination of Cenozoic Sea Temperatures Using *Hiatella arctica* (Linné). *Palaeogeography Palaeoclimatology Palaeoecology* (Netherlands) 5:213-233.

Struhsaker, J. W.
1966. Breeding, Spawning, Spawning Periodicity and Early Development in the Hawaiian *Littorina: L. pintado* (Wood), *L. picta* Philippi and *L. scabra* (Linné). *Proc. Malacological Soc. London* 37:137-166.
1968. Selection Mechanisms Associated with Intraspecific Shell Variation in *Littorina picta* (Prosobranchia: Mesogastropoda). *Evolution* 22:459-480.

Struhsaker, J. W., and J. D. Costlow, Jr.
1968. Larval Development of *Littorina picta* (Prosobranchia; Mesogastropoda), Reared in the Laboratory. *Proc. Malacological Soc. London* 38:153-160.

Struhsaker, P.
1973. Systematics and Ecology of Hawaiian Bathyal Fishes. Ph.D. Dissertation, Univ. Hawaii. Honolulu, Hawaii.

Suter, H.
1908. Additions to the Marine Molluscan Fauna of New Zealand, with Descriptions of New Species. *Proc. Malacological Soc. London* 8:22-42.

Swainson, W.
1820-1823. *Zoological Illustrations, or Original Figures and Descriptions of New, Rare, or Interesting Animals Selected Chiefly from the Classes of Ornithology, Entomology, and Conchology*. Ser. 1, Vols. 1-3. London.
1821. *Exotic Conchology or Figures and Descriptions of Rare, Beautiful or Undescribed Shells*. London.
1822. Descriptions of Several New Shells, and Remarks on Others, Contained in the Collection of the Late Mrs. Bligh. Appendix in C. Dubois, *A Catalogue of the Rare and Valuable Shells which Formed the Celebrated Collection of the Late Mrs. Bligh*. London.
1823. The Characters of Several Rare and Undescribed Shells. *Philosophical Mag. and J.* 61:375-378.
1824. The Characters of Several New Shells Belonging to the Linnaean Volutae, with a Few Observations on the Present State of Conchology. *Quarterly J. Science, Literature, Arts* 17(33):28-38.
1828. The Characters of *Achatinella*, a New Group of Terrestrial Shells, with Descriptions of Six Species. *Quarterly J. Science, Literature, Arts* 1:81-86.
1840. *A Treatise on Malacology or the Natural Classification of Shells and Shell-fish*. 419 pp. London.

Switzer-Dunlap, M., and M. G. Hadfield
1977. Observations on Development, Larval Growth and Metamorphosis of Four Species of Aplysiidae (Gastropoda: Opisthobranchia) in Laboratory Culture. *J. Experimental Marine Biology and Ecology*. 29:245-261.

Sykes, E. R.
1900. In D. Sharp (ed.), 1899-1913. *Fauna Hawaiiensis: Being the Land Fauna of the Hawaiian Islands*. . . . 3 vols. Cambridge: Cambridge Univ. Press.

Tapparone Canefri, C.
1880. Glanures dans la faune malacologique de l'ile Maurice. Catalogue de la famille des muricidés (Woodward). *Mém. Société Malacologique de Belgique*, pp. 9-99.

Taylor, D. W., and N. F. Sohl
1962. An Outline of Gastropod Classification. *Malacologia* 1:7-32.

Taylor, J. B.
1967. The Biology of *Peristernia chlorostoma* Sowerby, 1825. Master of Science Thesis (B), Univ. Hawaii. Honolulu, Hawaii.
1975. Planktonic Prosobranch Veligers of Kaneohe Bay. Ph.D. Dissertation, Univ. Hawaii. Honolulu, Hawaii.

Taylor, J. D.
1968. Coral Reef and Associated Invertebrate Communities (Mainly Molluscan) Around Mahé, Seychelles. *Proc. Royal Soc. London* (B)254:129-206.

Tesch, J. J.
1949. Heteropoda. *Dana Report* 34.

Thaanum, D.
1921. *Tapes philippinarum* in the Hawaiian Islands. *Nautilus* 34(3):107.
1927. Foreign Shells Imported into the Hawaiian Islands. *Nautilus* 40(4):133-134.

Thiele, J.
1912-1919. Scissurelliden und Fissurelliden. *Conchylien Cabinet* 2(36):1-168.
1929-1935. *Handbuch der systematischen Weichtierkunde*. Jena: Gustav Fischer.

Thompson, T. E.
1970. Eastern Australia Pleurobranchomorpha (Gastropoda, Opisthobranchia). *J. Zoology* (London) 160:173-198.
1972. Chromodorid Nudibranchs from Eastern Australia (Gastropoda, Opisthobranchia). *J. Zoology* (London) 166:391-409.

Thompson, T. E., and I. Bennett
1970. Observations on Australian Glaucidae (Mollusca: Opisthobranchia). *Zoological J. Linnaean Soc.* 49(3):187-197.

Thompson, T. E., and D. J. Slinn
1959. On the Biology of the Opisthobranch *Pleurobranchus membranaceus*. *J. Marine Biological Assoc. United Kingdom* 38:507-524.

Thorson, G.
1940. Studies on the Egg Masses and Larval Development of Gastropods from the Iranian Gulf. *Danish Scientific Invest. Iran* 2:159-238.

Thunberg, C. P.
1793. *Travels in Europe, Africa and Asia Performed between the Years 1770 and 1779*. Vol. 3. London.

Tiedeman, A.
1966. Recent Rare Finds on Island of Maui. *Hawaiian Shell News* 14(12):2.

Tinker, S.
1949. The Hawaiian Tun Shells. *Pacific Science* 3(4):302-306.
1952. *Pacific Sea Shells*. 230 pp. Honolulu: Mercantile.
1958. *Pacific Sea Shells*. (Rev. ed.). Vermont: Tuttle.

Tomlin, J. R. le B.
1915. Description of a New *Rissoina*. *J. Conchyliologie* 14(11):321-322.
1935a. The Marine Mollusca of Christmas Island, Indian Ocean. *Bull. Raffles Mus.* 9:74-84.
1935b. Catalogue of Recent *Latiaxis*. *J. Conchology* 20:180-183.
1944. Deshayes' Review of *Terebra*. *J. Conchology* 22:104-108.

Townsend, J. K.
1839. *Narrative of a Journey across the Rocky Mountains to the Columbia River, and a Visit to the Sandwich Islands, Chili, etc., with a Scientific Appendix*. Philadelphia.

Trego, K.
1974. Color Variations of *Conus emaciatus* Reeve, *Conus spiceri* Bartsch and Rehder, and *Conus textile* Linnaeus. *Veliger* 17(1):68-69.

Tryon, G. W., Jr.
1879-1913. *Manual of Conchology*. Philadelphia, Ser. 1, Vols. 1-17 (Continued by H. A. Pilsbry, Vol. 10, Pt. 2, etc.).

Tullis, R. E.
1968. Relationships Between *Stylifer linckiae* and its Host, *Linckia multifora*. Master of Science Thesis (B), Univ. Hawaii. Honolulu, Hawaii.

Turner, R. D.
1955. The Family Pholadidae in the Western Atlantic and the Eastern Pacific. Part II — Martesiinae, Jouznnetiinae and Xylophaginae. *Johnsonia* 3(34):65-160.
1966. *A Survey and Illustrated Catalogue of the Teredinidae*. Mus. Comparative Zoology Harvard Univ.

Uchiyama, J.
1963. The Anatomy and Life History of *Teredo trulliformis* Miller. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.

Ulbrick, M. L.
1969. Studies on *Crucibulum spinosum* (Sowerby). *Proc. Malacological Soc. London* 38:431-438.

United States Dept. of the Interior
1973. *Draft Environmental Statement. Proposed Hawaiian Islands Wilderness Area. City and County of Honolulu, Hawaii*. Bureau of Sports Fisheries and Wildlife, Washington, D.C. (Mimeo.)

Vancouver, G.
1798. *Voyage of Discovery to the North Pacific Ocean, 1790-1795*. 3 vols. London: G. G. and J. Robinson.

Van Heukelem, W. F.
1966. Some Aspects of the Ecology and Ethnology of *Octopus cyanea* Gray. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.
1973. Growth and Life-span of *Octopus cyanea* (Mollusca: Cephalopoda). *Zoological J. London* 169:299-315.

Vaughan, T. W.
1907. *Recent Madreporaria of the Hawaiian Islands and Laysan*. U. S. National Mus. Bull. 59. 427 pp.

Viader, R.
1937. *Revised Catalogue of the Testaceous Mollusca of Mauritius and Its Dependencies*. Mauritius Inst. Bull. 1, Pt. 2, pp. 1-111.

Vignal, L.
1902. Descriptions de Cerithidés nouveaux. *J. Conchyliologie* 49:303-305.
1903. Sur les variétes du *Cerithium zebrum* Kiener. *J. Conchyliologie* 51:21-27.

Voss, G. L.
1963. *Cephalopods of the Philippine Islands*. U. S. National Mus. Bull. 234. 180 pp.

Waller, T. R.
1972. The Pectinidae (Mollusca: Bivalvia) of Eniwetok Atoll, Marshall Islands. *Veliger* 14(3):221-264.

Watson, D. E.
1961. The Life History and Morphology of a Marine Trematode, *Coitocaecum bathygobium* n. sp. from *Bathygobius fuscus* (Rüppell) in Hawaii. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.

Watson, M.
1973. Midgut Gland Toxins of Hawaiian Seahares: I. Isolation and Preliminary Toxicological Observations. *Toxicon* 11:259-267.

Watson, R. B.
1880. Mollusca of H. M. S. *Challenger* Expedition, Part 5, *J. Linnaean Soc.* 15:87-126.
1886. Report on the Scaphopoda and Gastropoda Collected by H. M. S. *Challenger* during the Years 1873-1876. *Rep. Scientific Results Voyage of H. M. S.* Challenger, Zoology, Vol. 15.

Weaver, C. S.
1960-1961. Hawaiian Marine Mollusks. *Recent and New Species Terebridae* 1(1-8):1-32 (1960); (9):34-36 (1961).
1963a. An Amazing Parasitic Mollusk. *Hawaiian Shell News* 11(6):1.
1963b. Harp Shells in Hawaii. *Hawaiian Shell News* 11(12):1.
1963c. *Conus coronatus* Gmelin New Geographical Record! *Hawaiian Shell News* 12(2):6.
1964a. Tiny Hawaiian *Octopus* has Toxic Bite. *Hawaiian Shell News* 11(8):7.
1964b. The Holotype of *Ostrea kamehameha* (Hawaii's Massive Fossil Oyster). *Hawaiian Shell News* 12(6):1.
1964c. New Geographical Record. *Hawaiian Shell News* 12(10):8.
1965a. Two Exciting Hawaiian Discoveries. *Hawaiian Shell News* 13(7):1.
1965b. The First Live *Cypraea labrolineata* found in Hawaii. *Hawaiian Shell News* 14(2):1.

Weinkauff, H. C.
1875. *Systematisches Conchylien-Cabinet von Martini und Chemnitz*. Die Familie Pleurotomidae.
1879. *Systematisches Conchylien-Cabinet von Martini und Chemnitz*. Die Gattungen *Marginella* und *Erato* (ed 2), Vol. 3, Pt. 4.

Wells, J. W.
1954. *Recent Corals of the Marshall Islands*. U. S. Geological Survey Prof. Pap. 260.

Wentworth, C. K.
1938. Marine Bench-Forming Processes: Water-Level Benching. *J. Geomorphology* 1:6-32.
1939. Marine Bench-Forming Processes. II. Solution Benching. *J. Geomorphology* 2:3-25.

Wenz, W.
1938-1944. *Handbuch der Paläozoologie. Allgemeiner Teil und Prosobranchia*. Berlin.

Wertzberger, J.
1968. Behavior of *Hiloa variabilis*. *Hawaiian Shell News* 26(6):1.

Whipple, J. A.
1966. The Comparative Ecology of the Hawaiian *Littorina* Ferussac (Mollusca: Gastropoda). Ph.D. Dissertation, Univ. Hawaii. Honolulu, Hawaii.

White, K. M.
1947. On a Collection of Marine Molluscs from Ceylon. *Proc. Malacological Soc. London* 27(5):199-205.

Wilson, B. R.
1969. Use of the Propodium as a Swimming Organ in an Ancillid. *Veliger* 11:340-342.

Wilson, B. R., and K. G. Gillett
1971. *Australian Shells*. Sydney: Reed.

Winckworth, R.
1946. Synonyms of *Glossodoris*. *Proc. Malacological Soc. London* 26:153-154.

Wolfe, C.
1973. *Strombus wilsoni* Identified in Hawaii. *Hawaiian Shell News* 21(9):1, 3.
1974. New Cassid Recorded from Hawaii. *Hawaiian Shell News* 22(7):1, 3.
1975a. The Cymatiidae of Hawaii. *Hawaiian Shell News* 22(3):1, 6.
1975b. A Puzzling Hawaiian *Bursa*. *Hawaiian Shell News* 22(10):12.

Wood, W.
1818. *Index Testaceologicus: Or a Catalogue of Shells, British and Foreign*. London.
1828. *Supplement to the Index Testaceologicus: Or a Catalogue of Shells, British and Foreign*. London.

Woodring, W. P.
1925. *Miocene Mollusks from Bowden, Jamaica. Pelecypods and Scaphopods*. Carnegie Inst. Washington. Pub. 366.

Wu, S. K.
1965. Comparative Functional Studies of the Digestive System of the Muricid Gastropods *Drupa ricina* and *Morula granulata*. *Malacologia* 3(2):211-233.
1969. Some Chitons from Taiwan (Formosa). *Malacological Rev.* 2:103-111.

Yamamoto, T., and T. Habe
1974. *Scintillona stigmatica* (Pilsbry) New to Japan. *Venus* 33(3):116.

Yap, W. G.
1974. Population Biology of the Little-neck Clam, *Tapes philippinarum*, in Kaneohe Bay, Hawaii. Master of Science Thesis, Univ. Hawaii. Honolulu, Hawaii.

Yen, T. C.
1941. A Review of Chinese Gastropods in the British Museum. *Proc. Malacological Soc. London* 24(5/6):170-289.

Yonge, C. M.
1952. Studies on Pacific Coast Mollusks. II. A Note on *Kellia laperousii* (Deshayes). *Univ. California Publ. Zoology* 55:451-454.
1962. On the Primitive Significance of the Byssus in the Bivalvia and Its Effects in Evolution. *J. Marine Biological Assoc. United Kingdom* 42:113-125.

Young, D. K.
1966. Systematics, Food and Functional Morphology of the Feeding Apparatus of Some Dorid Nudibranchs. Ph.D. Dissertation, Univ. Hawaii, Honolulu, Hawaii.
1967. New Records of Nudibranchia (Gastropoda, Opisthobranchia) from the Central and West-Central Pacific with a Description of a New Species. *Veliger* 10(2):159-173.
1969. *Okadaia elegans*, a Tube-boring Nudibranch Mollusc from the Central and West Pacific. *American Zoologist* 9:903-907.

Young, R. E.
1972a. The Systematics and Areal Distribution of Pelagic Cephalopods from the Seas off Southern California. *Smithsonian Contrib. Zoology* 97:1-108.
1972b. Brooding in a Bathypelagic Octopus. *Pacific Science* 26(4):400-404.
1975a. *Leachia pacifica* (Cephalopoda, Teuthoidea): Spawning Habitat and Function of the Branchial Photophores. *Pacific Science* 29(1):19-25.
1975b. Function of the Dimorphic Eyes in the Midwater Squid *Histioteuthis dofleini*. *Pacific Science* 29(2):211-218.
Zimmerman, E. C.
1948. *Insects of Hawaii*. Vol. 1. *Introduction*. Honolulu: Univ. Hawaii Press.

INDEX

Roman type indicates valid taxa as utilized in this volume. Other names in *italics* are synonyms, or names that have been superseded. Subfamilies and other higher taxa are printed in CAPITAL and SMALL CAPITAL letters.

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

ADDENDA AND CORRIGENDA

After the manuscript of this book was in type, the following additions and corrections were noted.

p. 41. Fig. 10. The drawings of the development of *Diodora* are from C. F. Boggs, 1978. Development of Hawaiian *Diodora*. *Hawaiian Shell News* 26 (10):3-4.

p.120. The synonym of *Bittium parcum* should read *Bittium hawaiiense* Pilsbry and Vanatta, 1905.

p. 156. The synonym of *Epitonium perplexum* should read *Scalaria lamellosa* Lamarck, Bryan, 1915.

pp. 159-168. Additional record in the Eulimidae: The Pilsbry (1917) record of *Melanella labiosa* (Sowerby) may represent specimens of *Balcis thaanumi*.

p. 193. The synonym of *Cypraea granulata* should read *C. madagascariensis* Gmelin, Martens and Langkavel, 1871.

p. 241. The synonym of *Drupa morum* should read *D. horrida* Lamarck, Tryon 1880.

p. 302. *Mitra subrostrata* Sowerby, 1874 is not a synonym of *Mitra (Nebularia) ticaonica*.

pp. 313-333. Additional record in the Costellariidae: At least one specimen of *Vexillum (Pusia) speciosum* Reeve, 1844, is known from Hawaiian waters.

p. 331. The synonym of *Vexillum (Pusia) piceum* should read *Vexillum millecostatum* Broderip, J. Cate, 1963.

p. 331. A synonym of *Vexillum (Pusia) suavis* (Souverbie, 1865) is *V. exquisitum* (Garrett, 1873), J. Cate, 1963.

THIS VOLUME WAS SET IN
TIMES ROMAN AND TIMES ITALIC TYPE
AND PRINTED BY
FISHER PRINTING CO., INC.
HONOLULU, HAWAII