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REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

XXVI.

THE CTENOPHORES.

By Henry B. Bigelow.

With Two Plates.

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No. 12.— *Reports on the scientific results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905,* Lieut. Commander L. M. Garrett, U. S. N., *Commanding.*

XXVI.

The Ctenophores.

By Henry B. Bigelow.

The "Albatross," during her cruise in the Eastern Tropical Pacific, 1904–1905, collected only six species of Ctenophores, none of which are new. But the series is of greater interest than the paucity of its members would suggest, because up to the present time we have had almost no data of the fauna of the region and because the genus Hormiphora is represented by a series so large that it throws new light on the interrelationships of the various described species. The opportunity to study the material fresh from the net, which I owe to Mr. Agassiz, has been of great assistance.

CYDIPPIDA.

PLEUROBRACHIIDAE Chun.

Pleurobrachia Flemming.

Two Atlantic species of this genus are generally recognized, *pileus* known from both sides of the north Atlantic, and the Mediterranean *rhodopsis*, while Moser (:09) has recently described a third, *crinita*, from Greenland. Mayer (:12) describes a fourth, *P. brunnea*, but this is probably identical with *Hormiphora spatulata* Chun (p. 377). From the Indo-Pacific two species, *globosa* Moser and *pigmentata* Moser, are listed by Moser (:09) who has most recently surveyed the genus. *Pleurobrachia pileus*, *P. rhodopsis*, and the Pacific form described by A. Agassiz ('65) as *P. bachei* are very closely allied to one another. Moser (:09) considers *bachei* a synonym of *pileus*. The exact relationships of these forms have not been clear, partly because the Mediterranean form is known only from Chun's account

of its young, partly because *bachei* has only very recently been figured (Torrey, :**04**, pl. 1, fig. 1).

Fortunately the Museum of Comparative Zoölogy contains a large series of adult and young *P. pileus,* several specimens of *rhodopsis* showing two stages in development, and 134 of *bachei* (one of them belonging to Agassiz's original material). The "Albatross" specimens, from the west coast of Mexico, are without question the latter, and from the standpoint of geographic distribution the opportunity to compare this form with the two Atlantic ones has proved instructive.

I. *Pleurobrachia pileus* and *P. rhodopsis.* According to Chun (:**80**) and to Moser (:**03**) the chief distinctions between these two are that in the latter the ribs are very short, and that the junction of the adradial canals with the meridionals is at the same level as the funnel. But the material which I have examined shows that neither of these distinctions holds good. One can hardly compare Chun's young (5–7 mm.) *rhodopsis* ('**80**, taf. 2, figs. 5, 6) with A. Agassiz's drawing of *pileus* at about the same stage ('**65**, p. 32, fig. 47) without being struck by the resemblance between the two, and by the fact that the ribs in the former are of about the same length as in the latter; but in neither is the exact level of the junction of canals shown clearly. Our smallest Mediterranean specimen is rather further advanced; the ribs are proportionately longer, now reaching from near the apex to about the mid level of the stomach; and the tentacular sheaths and bases are larger. The specimen differs from Chun's figure in having the opening of the sheaths nearer the aboral pole, while the adradial canals open into the meridionals slightly aboral to the funnel, instead of on a level with it.

Unfortunately I have no corresponding stage of *pileus* for comparison, but this difficulty does not hold for our largest and most interesting *rhodopsis.* This specimen though obviously somewhat shrunken is 9 mm. long. Probably it was at least 10 mm. in life. The ribs are much longer than in the younger specimen; they now reach from close to the aboral pole over $\frac{2}{3}$ of the length of the stomach; the tentacle-bases and -sheaths have increased in size, and the latter nearly equal the oral ends of the ribs; and the junction of adradial and meridional canals is appreciably above the level of the funnel. I was able to compare this example with *pileus,* at a corresponding stage, and of about the same size (9 mm.), and the only differences I could find between them were that the funnel-canal was slightly longer in *pileus,* the ribs slightly shorter. But in other specimens of *pileus* only slightly larger the funnel-canal is shorter, and the ribs longer;

in other words these differences are no greater than may be found in large series of *pileus*, which, as Moser has pointed out, shows great individual variability. In fact, it would be impossible to pick out this Mediterranean specimen from a series of *pileus* similarly preserved and of about the same size.

We must remember that with preservation Ctenophores almost always suffer more or less alteration of form and proportion, even though they may be in good condition anatomically, and for this reason slight differences in form and proportion between preserved specimens are to be looked on with suspicion. This specimen, which is the oldest Pleurobrachia yet described for the Mediterranean would require but little additional development for it to attain the stage so beautifully figured by L. Agassiz for *pileus*. All that would be necessary is progressive growth of the aboral half of the body resulting in proportionately longer stomach, ribs, and tentacular sheaths, and bases. This is exactly the line of development in *pileus*; and I have been able to follow it through successive steps to a specimen 24 mm. long. The most interesting feature of growth is the increasing size of the tentacular sheaths.

The progress of the change is already to be seen in the small Mediterranean specimens, and in larger *pileus* of 15–20 mm. The sheaths keep pace with the ribs, finally reaching nearly to the oral pole of the body. Moser (**: 09**) has pointed out that the body, at first nearly globular, becomes more and more cylindrical as it increases in size, and that the stomach becomes proportionately longer, and that the tentacle-bases grow proportionately larger, and lie nearer and nearer the stomach. And my own studies entirely substantiate her account. In the adult condition the tentacular bases and the gastric cavity are variously affected by different preservatives. In life, so far as I have seen, the sheaths are always at an appreciable distance from the oesophageal canals and gastric wall; and the relative positions of the organs are retained fairly well in osmic-acid material. But in all the available specimens preserved in formalin the gastric cavity is so much dilated that its normal flattening is entirely obscured, and it is in close contact with the tentacle-sheaths. This warns us how cautiously we must employ such characters in preserved Ctenophores, especially in describing new species. The facts outlined above show that there is no sound distinction between *rhodopsis* and *pileus*. Instead of being a local species peculiar to the Mediterranean as Moser supposed, the former is merely an intermediate stage in the development of the latter, and therefore there is no longer any reason

to query the record of "*rhododactyla*" (= *pileus*) from the Black Sea by Sovinsky (:**04**). Mayer (:**12**, p. 13) suggests that some of the Mediterranean records, and the record from Bermuda, may be based on young larval Bolinopsis. But such a mistake could hardly be made by anyone familiar with Ctenophores, for the tentacular sheaths of Pleurobrachia separate it at a glance from young of any of the Lobata. Larval Pleurobrachias so young that the tentacles still lie on the surface of the body might, of course, be confused with other larvae: but such criticism does not apply to the Mediterranean specimens noted above, nor to Chun's specimens.

We do not yet know whether the Mediterranean Pleurobrachias ever reach the large size attained by their Atlantic relatives. It may be that they represent a diminutive local race. Such races are not unknown among pelagic coelenterates; witness the progressive decrease in size in Cyanea as we follow it from north to south along the American coast. But such a difference alone does not warrant specific separation, and therefore I have no hesitation in relegating *rhodopsis* to the synonymy of *pileus*, of which it is at most a variety.

II. *Pleurobrachia pileus* and *bachei*. Torrey believes that these two are distinct. But Moser (:**09**) in her most recent discussion of the subject, unequivocally unites them, on the grounds that the slight difference mentioned by Torrey as distinctive of *bachei*, *i. e.* long funnel-canal, small tentacular sheaths, and junction of adradial and meridional canals aboral to the level of the funnel, are to be explained as due to different states of contraction. The only detail which she found difficult of explanation was Agassiz's statement that the tentacular sheaths of *bachei* open oral to the level at which the adradial canals open into the meridionals, instead of aboral to it, as in Torrey's specimens and in *pileus*. But this difficulty is not a real one because in one of Agassiz's original specimens, which I have been able to study and which is still in good condition, the openings of the sheaths bear precisely the same relation to the meridional canals that they do in *pileus*. Perhaps the original account was drawn from a violently contracted, or otherwise distorted example.

Inasmuch as Moser uses geographic distribution as a further reason for uniting the two species, I may point out that there is some confusion in the localities mentioned by her. The "Gulf of Georgia," given by A. Agassiz as the type locality for *bachei* is not, as she supposed, the coast of the state of Georgia, on the east coast of America and in about the same latitude as Bermuda, but is on the west coast, between Vancouver Island and the mainland, lat. 49° N., long. 124° W.

This fact, of course, removes the weight from the argument that it would be surprising if the *P. pileus* of Bermuda were replaced by another species at the type locality of *bachei*. Furthermore "Washington Territory" (Moser, **:09**, p. 145) is on the west, not on the east coast of North America.

Moser's discussion of *bachei* was drawn perforce from the published accounts, which certainly do not contain anything to show that it is not *pileus*, or at most a local Pacific variety of the latter. I was therefore particularly glad to have the opportunity of testing the validity on a series consisting of one of A. Agassiz's specimens from the Gulf of Georgia of moderate size, three from Puget Sound, one hundred and thirty-one specimens, taken by the "Albatross" off the coast of southern California, and many young specimens in the present collection from Acapulco, west coast of Mexico. All of these agree with *pileus* of corresponding ages except for the minor features that all have an unusually long funnel-canal, very short tentacular sheaths and bases, and by the fact that the adradial canals open into the meridionals well above the funnel level, that is to say, the characteristics are precisely those noticed by Torrey (**:04**) in his San Diego specimens. All these characters are shown by the youngest specimens, 3–4 mm. high. If we compare them with *pileus* at a corresponding stage, whether the Altantic (Agassiz, **'65**) or the Mediterranean race (Chun, **'80**) the difference is a striking one. In the Pacific example the funnel-canal is proportionately nearly twice as long as in one from the Atlantic or Mediterranean; and the opening of the tentacular sheaths and the junction of adradial and meridional canals much nearer the aboral pole. The differences do not disappear with growth; but are evident in specimens 10–12 mm. high. By this time the tentacular sheaths and bases have increased in size, growing toward the oral pole; but they lag far behind *pileus* (*cf.* Torrey, **:04**, pl. 1, fig. 1, with L. Agassiz, **'49**, pl. 3, figs. 1, 2). The funnel-canal is still longer than the digestive tract; whereas in *pileus* it is usually considerably shorter at all stages.

Our Puget Sound specimens are slightly larger, our Californian ones slightly smaller, than the San Diego material studied by Torrey; but they agree very well with his figure, except for the length of the ribs which depends on size, as might be expected. But in all, irrespective of contraction (and several are much shrivelled), the funnel-canal is longer than the gastric cavity, and the junction of adradial canals and meridionals lies at a level about half way between funnel and apex. Now, in all the Atlantic and Mediterranean specimens that

I have seen, the funnel is at least no longer than the oesophagus, and the canal junction lies on a level with, or slightly above the funnel. Apart from these features comparison, side by side, of considerable series has failed to reveal a single difference between the Atlantic and Pacific forms.

Moser (:09) has pointed out that *pileus* is extremely variable in form and proportions, both individually and with different stages in growth, a conclusion which my own observations substantiate; and the "*bachei*" type may well lie within the normal limits of variation of *pileus,* as Moser supposes, though I can not prove this as a first hand observation. Nevertheless the fact remains that all the Pleurobrachias of the *pileus* type yet recorded from the west coast of North America belong to a variety which is certainly not the prevailing one in the north Atlantic, although it may occur there. But the "*bachei*" form is apparently not generally distributed over the Pacific as a whole, for it is known only from the west coast between lat. about 49° N. and about 17° N.; and the Pleurobrachia record from New Zealand, is typical *pileus,* as are the records from the Seychelles, from South Africa, and from the Antarctic (Moser, :09).

Moser thinks it probable that the Pleurobrachias of the west coast of North America are carried thence by the cold "Polarstrom," and the "globular Ctenophore" mentioned by Chamberlain (:06) as common off the Alaskan coast is probably a Pleurobrachia, as is the "*Beroe octoptera*" of Mertens ('33) from Behring Straits. But to show how scanty our knowledge in this field is, I would point out that there is not another record of the genus from either side of the Pacific north of Puget Sound. Furthermore, I find no Pleurobrachias in all the extensive collections which have been gathered by the "Albatross" in the northwestern Pacific, though her voyages in that region have extended along the entire coast of Alaska, Behring Sea, the Aleutian Islands, and Japan, and, from year to year, have been prosecuted in every month from May to October.

In the meantime, however, some disposition must be made of the Californian Pleurobrachia in our system of classification. Decidedly it is not a distinct species. But on the other hand to unite *bachei* unreservedly with *pileus,* of which it is undoubtedly a component, will only hide the need of further investigation. Among the higher vertebrates the solution would be a subspecies, but inasmuch as this rank is not recognized among Ctenophores, Medusae, or Siphonophores, the most satisfactory way is to consider the form, for the time being, a variety.

Four more Pleurobrachias must still be considered:— *globosa* Moser, *pigmentata* Moser, *striata* Moser, and *crinita* Moser. The original specimens of *globosa* were all very small (1–6 mm. high), and immature. Slightly larger examples, up to 8 mm., have been described by Browne (**:05**) as *globosa* var. *ceylonensis*. The only important difference between them and Moser's material was that the ribs were somewhat longer; but this difference was evidently a concomitant of growth; in fact just what is to be seen in *pileus*. Moser mentions as its distinctive features:— very short ribs, long funnel-tube, opening of the sheaths on a level with the aboral ends of the ribs, and the fact that the adradial canals open into the meridionals in the oral $\frac{1}{3}$ of the latter, *i. e.* slightly above the level of the funnel. All but the last of these characters are shared with the young *bachei* in the present collection. But in the latter the adradial canals join the meridionals above the middle of the latter, just as they do in *pileus*.

It is unfortunate that we do not know what changes, if any, *globosa* undergoes with advancing growth; at present it is impossible to determine its status definitely. But the difference between it and all the other Pleurobrachias yet described is so striking that it must be recognized as a distinct species, at least provisionally. It is to be hoped that its adult will soon be discovered.

Pleurobrachia pigmentata and *P. striata* are very easily distinguished from all other Pleurobrachias by the pigmentation of the paddle-plates. In general appearance they suggest Tinerfe, but, unlike that genus, all the meridional canals develop sexual products. The differences between *pigmentata* and *striata* are that the latter is more nearly cylindrical than the former and has a larger mouth, the fact that its ribs are unequally spaced, slightly shorter and narrower, and that the cilia are larger. But these are just the characters which are most readily altered by preservation; I have seen the differences in form, in the mouth, and in the cilia outlined above appear after preservation in a series of *pileus* which I had previously examined and found indistinguishable in life, and that, too, when all were put into the same bottle of formalin. The spacing of the ribs may be of more importance but in shrivelled *pileus* the spacing often becomes unequal. I therefore doubt whether *striata* is distinguishable from *pigmentata*. *P. crinita* is separated from its relatives by "die konische Gestalt, die grosse Länge der Rippen und Schwimmplättchen und durch die Form des Mundes, der in vier Zipfeln von hornartig gekrümmter Gestalt ausgezögen ist" (Moser, **:09**, p. 148). These features are not

paralleled in the large series of the only other Arctic Pleurobrachia, *P. pileus*, which have been examined by Moser, and by the writer.

Finally, *Euplokamis australis* Benham (:**07**) is apparently a Pleurobrachia, to judge from its tentacular sheaths. In form it resembles the more cylindrical specimens of *pileus*, though it differs from specimens of that species of corresponding size in having much shorter tentacular sheaths, and longer ribs. But the fact that *pileus* is now known from New Zealand suggests that *australis* is an extreme variant of that unstable form.

Pleurobrachia pileus Fabricius. var. bachei A. Agassiz.

Pleurobrachia bachei A. Agassiz, in L. Agassiz, '**60**, p. 294; '**65**, p. 34; Moser, :**03**, p. 6; Torrey, :**04**, p. 46.

Acapulco Harbor, surface, about one hundred and fifty specimens from 2–4 mm. high. Also, off the coast of California, lat. 37° N., long. 122° 20′ W., 131 specimens, 7–12 mm. high. Puget Sound, three specimens, 10 mm. high. Gulf of Georgia, one specimen, collected by A. Agassiz, 1865. This example is now so much flattened that its dimensions can not be determined. But it is large.

The more important features of the series have been described above.

Hormiphora L. Agassiz.

Hormiphora is closely allied to Pleurobrachia, from which it is separable only by the fact that the tentacular bases and sheaths lie close to the paragastric vessels, instead of mid-way between them and the outer surface of the body. And I agree with Mayer (:**12**) that it will probably be united with Pleurobrachia in the future. But it may be retained temporarily until its members are better known.

The collection contains so large a series of one species of this genus (upwards of two hundred and sixty specimens) that it affords an opportunity to test the constancy of some of the characters on which the various Hormiphoras are based. The latest account of the genus is by Moser (:**09**) who recognizes no less than nine species, *H. hormiphora* Gegenbaur ('**56**),[1] *spatulata* Chun, *palmata* Chun, and

[1] This species has universally been called *H. plumosa*, under which name L. Agassiz ('**60**) made it the type species of the genus. But the specific name *plumosa* was not proposed by Sars until 1857, while Gegenbaur had described it as *Cydippe hormiphora* the year before. Under the International rules of zoölogical nomenclature the older name must be used.

punctata Moser from the Atlantic, *ochracea* Agassiz and Mayer, *fusiformis* Agassiz and Mayer, *sibogae* Moser, *amboinae* Moser, and *japonica* Moser from the Indo-Pacific. The Californian "*Mertensia ovum*" of Torrey is also evidently a Hormiphora. My own studies on a very large series have convinced me that not all of these are good species, and the necessity of identifying our own material requires a preliminary revision of the genus as a whole.

To begin with, *ochracea* can at once be accorded a definite status, if the character by which it is distinguished, entire absence of tentilla except at a very young stage (Moser, : **03**), be normal. And inasmuch as two collections, made several years apart and at localities as far separated as off the west coast of America and the Malayan waters agree in this respect, and furthermore, when Moser, who alone has described adults of *ochracea* has also studied other members of this genus, we can hardly credit the absence of tentilla to mutilation. I have never seen a specimen of it myself. Apart from tentacular structure, *ochracea* may possibly be distinguished by very long meridional canals contrasted with short ribs; but as we shall see, this character is a variable one.

H. spatulata, according to Chun's ('**98**) account and figures, is readily distinguished from all other Hormiphoras by the fact that the tentacular sheaths diverge widely from the stomach at their oral ends, and that it is only the upper (aboral) ends of the bases of the tentacles which lie close against the gastric wall. And this account has recently been corroborated by Moser (: **09**) for a well preserved specimen from the west coast of Spain. A Ctenophore with this same characteristic, and resembling *spatulata* likewise in general form, has been described from the East coast of North America by Mayer (: **12**) as *Pleurobrachia brunnea*. According to him it is distinguished from *spatulata* mainly by the presence of terminal knobs on the tentacles; but as Chun's figure of *spatulata* ('**88**, taf. 3, fig. 3) shows a terminal knob-like tentillum on one of the tentacles, it appears that the supposed difference in this respect is not valid. *P. brunnea* is almost certainly a synonym of *spatulata*. In all the numerous Hormiphoras of the "Albatross" collection (p. 38) the tentacular sheaths are in close contact with the oesophagus throughout their length, so there is a discontinuity in this respect, sufficient to distinguish them from *spatulata*. Larvae of *spatulata* have two kinds of tentilla, ordinary filiform, and large spatulate. But in the adult the latter are lost (Chun, '**98**, taf. 3, fig. 4).

The species which remain are less easily disposed of. The form

described by Chun ('98) as *palmata* is especially confusing because the name was based on the combination of a very early and of a mature stage the connection of which with each other was only a supposition. His young "*palmata*" is characterized by having peculiar eolid tentilla as well as filiform ones, and in this it agrees with the type species of the genus, *H. hormiphora.* It further agrees with *hormiphora* in general form, and in the fact that the adradial canals meet the meridionals at about the level of the funnel. The only distinction between this larva, and the adult *H. hormiphora,* except for differences in development which might be expected, is that the eolid tentilla are proportionately larger, more numerous, and with fewer processes, in the former than in the latter.

Now, although *H. hormiphora* is common in the Mediterranean (Gegenbaur, '56, Sars, '57, Chun, '80), and the adult has been well described and figured (as "*plumosa*") by Chun, and by Mayer (:12) our only information about its young stages is his figure of a very young larva, so young, in fact (2 mm. long) that filiform tentilla alone have yet appeared; from the stoutness of its ribs, too, it is obviously much younger than his young "*palmata.*" Chun himself has observed that the very youngest "*palmata,*" 3 mm. long, have no eolid tentilla, and that the first tentilla to appear are the filiform ones.

We need assume merely that the eolid tentilla of the young "*palmata*" become more complex individually, without a corresponding increase either in size or in number beyond the stage which Chun figured, to attain the conditions seen in the adult *H. hormiphora.* There is certainly no evidence that the eolid tentilla would not undergo further individual development. Indeed the figure (Chun, '88, taf. 3, fig. 1) shows that the oldest (terminal) ones have more lateral papillae than the younger ones. And judging from conditions in a group of coelenterates, *i. e.* the Siphonophores, in which complex tentilla are the rule, not the exception, progressive development of the lateral processes is just what we might expect.

The developmental series from larval *H. hormiphora,* through Chun's young "*palmata*" stages in which the eolid tentilla appear, and become more numerous and complex, to the adult *hormiphora* reached by progressive development of the individual tentilla as well as of the animal as a whole, is thoroughly in accord with the facts as we know them; there is nothing to forbid the connections here outlined. On the other hand the association of the young "*palmata*" with the full-grown Hormiphora which Chun ('98) believed to be its adult is supported by no actual evidence. The five large examples had no eolid

tentilla, and the tentacle-bases and -sheaths agree no better with the young *palmata* than do those of the adult *hormiphora*. Chun himself says ('98, p. 18) "Die Beobachtung des lebenden Thieres wird erst einen sicheren Entschied liefern, ob dieser .... Cydippiden den oben geschilderten Jungendformen zugehören." The young "*palmata*" was taken in the Straits of Gibraltar.

But even though I believe Chun's young "*palmata*" is a stage in the development of *H. hormiphora*, the name *palmata* is not to be abandoned, but must be applied to the adult Hormiphora described by Chun under that name, which proves to be an important and widely distributed species.

If we turn now to the Indo-Pacific Hormiphoras, of which *ochracea* has already been treated, we find that two of them, *amboinae* and *japonica*, closely resemble Chun's adult *palmata*, and the same is true of the large Eastern Pacific series. All of them are ovoid in general form, flattened but slightly, if at all, in the pharyngeal plane and they are proportionally much longer than *H. hormiphora*. In all of them the adradial canals join the meridionals at about the level of the funnel, or very slightly above it; the tentacle-sheaths are closely apposed to the gastric tract throughout their length and reach about to the end of the meridional canals, and open above the level of the funnel; and all have filiform tentilla.

The characters separating *palmata*, *amboinae*, and *japonica* from one another are the precise height at which the tentacular sheaths open to the exterior, the exact outlines of the sheaths and of the bases of the tentacles, the form of the apex, whether truncate or not, and the proportional length of meridional canals and ribs. But the very large series collected by the "Albatross," which I examined both in life and after preservation, show that all these characters are variable, both normally and with contraction, and that the conditions illustrated by the three forms are well within the limits of variability of a single species.

In *amboinae* the sheaths open close to the apex, which is truncate; in *palmata* they are only about one third the distance from funnel to apex, *japonica* is intermediate between the two, and our specimens afford further connecting links; while the truncation of the apex in *amboinae* is a contraction-phase, paralleled by many of our examples. The outlines of the sheaths are equally variable, being more or less voluminous, and so is the form of the tentacular base, which is variously curved, or straight. These features are much affected by preservation — furthermore, as shown in the figures (Plate 1, fig. 5, 6),

the proportionate length of ribs and meridional canals is individually variable, even in the different canals of a given individual, while different individuals from one haul show the extremes illustrated by *palmata* and *japonica* as well as intermediates connecting them. Judging from these facts, no course is open but to refer *amboinae*, *japonica*, and the "Albatross" specimens to *palmata*. That this species should occur both in the Atlantic and in the Indo-Pacific is not at all surprising, indeed, the case exactly parallels that of many oceanic Medusae and Siphonophorae.

H. fusiformis Agassiz and Mayer, agrees with *palmata* in its general form, in its tentilla, and in the outlines of its tentacular sheaths, but differs, according to their account, in the fact that the adradial canals join the meridionals above the level of the funnel. Furthermore, their figure (: **02**, pl. 13, fig. 59) shows the tentacle arising from one end of the base, instead of from the middle, something which, as Moser has pointed out, does not occur in any pleurobrachiid. Fortunately I have been able to study a large series from the Hawaiian Islands, including two specimens labelled by Mayer himself, and though all of them are more or less fragmentary, they are in good enough condition to show that the canal-junction is at the level of the funnel, just as in the eastern Pacific series, and that the structure of the bases of the tentacles is of the usual type. In short, there is nothing to separate them from *palmata*. Therefore *fusiformis* can safely be relegated to the synonymy of *palmata*. It is still a question whether *palmata* is really distinct from *hormiphora*, or whether the two are varieties of a single species; and until the matter is settled, it is better to retain both names.

One other Ctenophore closely resembles *H. palmata*, the "*Mertensia ovum*" of Torrey (: **04**, pl. 1, fig. 1), which, as Moser has pointed out, has nothing to do with the genus Mertensia. Its status is somewhat confusing because Torrey does not refer to the figure in his text, nor does he list *Mertensia ovum* as having been taken at San Diego, where, indeed, its presence would be most unlikely. Judging from the account of his *Euplocamis californensis* (Torrey, : **04**), I have no doubt that the figure in question belongs to that form, and that the legend on the plate is erroneous. So far as the figure shows, the species is probably not separable from *H. palmata* with which it agrees in general. The only points of difference are that the meridional canals reach almost (but not quite) to the mouth, and that the tentacular sheaths are shorter than is usually the case in *palmata*. But I have seen one specimen of the latter (Plate **1**, fig. 2) almost exactly paralleling

Torrey's figure in the latter respect, though with shorter meridional canals. Without examining specimens I hesitate to assign a definite status to this form, though I am of the opinion that it will eventually prove to be *palmata*.

Hormiphora punctata Moser, is remarkable among Hormiphoras from the fact that the ribs are pigmented; a character in which it parallels *Pleurobrachia pigmentata* Moser. Unfortunately the single specimen (4 mm. long) was in very poor condition, and, to judge from the figure, much contracted. Better material will be required to show whether it is really generically distinct from Chun's *Tinerfe coerulea* which it much resembles in general appearance.

H. sibogae Moser is a species so easily distinguished from all other Hormiphoras by its very short meridional canals, small and short tentacle-sheaths, retracted apex, and junction of meridional and adradial canals well above the level of the funnel that there is no doubt of its validity. The only tentillum observed was of a peculiar trefoil-like outline.

Finally, we have the case of the *Beroe cucumis* of Mertens (**'33**). Moser (:**09**) has referred this species to "Cydippe," hesitating to locate it in either Pleurobrachia or Hormiphora, to one or other of which she believes that it belongs. Mertens's excellent figures show that it is undoubtedly a Hormiphora; but its exact relationships to the other members of that genus can be settled only by an examination of new material.

Hormiphora palmata Chun.

Plate **1**, figs. 1–6.

Hormiphora palmata Chun, **'98**, p. 17, pl. 3, fig. 2 (*non* pl. 3, fig. **1**) (*partim*).

Lampetia fusiformis Agassiz and Mayer, :**02**, p. 171, pl. 13, figs. 59, 60.

Hormiphora fusiformis Mayer, :**06**, p. 1134.

Hormiphora amboinae Moser, :**08b**, p. 8, pl. 1, fig. 4.

Hormiphora japonica Moser, :**07**, p. 450, :**08a**, p. 10, taf. 1, figs. 6–8.

? *Euplokamis californensis* Torrey, :**04**, p. 46.

? *Mertensia ovum* Torrey, :**04**, pl. 1, fig. 1.

Station 4600, about 200 specimens, 15–27 mm. long. A swarm was encountered at this Station on the surface.

Station 4627, 2 specimens, both about 17 mm. long.

" 4631, 2 " 25 and 15 mm. long.

Station 4638, 1 specimens, fragmentary.
" 4642, 1 " " " 16 mm. long.
" 4650, 2 " both 16 mm. long.
" 4652, 3 " 16 mm. long.
" 4656,
" 4682, 1 " 35 mm. long.
" 4689, 2 " both 22 mm. long.
" 4691, 1 " fragmentary.
" 4713, 1 " "
" 4718, 1 " 32 mm. long.
" 4729, 1 " 24 mm. long.
" 4731, 2 " 25 and 15 mm. long.
" 4735, 1 " fragmentary.
" 4741, 1 " 22 mm. long.

Also Hawaiian Islands, 19 specimens, all somewhat injured.

Southeast coast of Japan, 35 specimens, 10–35 mm. long, collected by the "Albatross."

Except as noted above, the material is in excellent condition, but unfortunately there are no very young stages. The specimens are all considerably longer than broad, more or less narrowed at each pole, and but slightly flattened in the pharyngeal plane. But, as shown in the accompanying table, the precise proportion between length and diameter varies considerably; and the same is true of the polar narrowing.

Table of dimensions and proportions: in the latter length is taken as the unit.

Dimensions			Proportions		
Length	Greatest diameter	Least diameter	Length	Greatest diameter	Least diameter
mm.					
8	5	4.5	1	.55	.50
9	6	5.5	1	.66	.60
9	6	6	1	.66	.66
12	8	6	1	.66	.50
13	13	12	1	1	.92
15	7	6.5	1	.46	.42
18	10	9	1	.55	.50
22	8	6	1	.36	.27
22	11	9	1	.50	.41
24	13	11	1	.54	.45
25	10	8	1	.40	.32
35	13	10	1	.37	.28

The best preserved specimens agree in general with the photograph (Plate 1, fig. 1); but one very large example is more spindle-shaped, approaching Agassiz and Mayer's (:02) figure of their *fusiformis*. The series from Station 4600 are all soft and flaccid, and in most of them the aboral pole is more or less retracted. But these specimens were collected before I joined the ship, and experiments showed that the difference in solidity and outline between them and the specimens collected later were due to differences in preservation. Differences in preservation, especially whether or not the specimens were stupified in chloretone, cause differences in the degree of protusion of the mouth, and in general form and proportions (*cf.* fig. 1, fig. 2).

Tentacles and *sheaths*. The tentacular sheaths are voluminous, and in the better specimens their form (Plate 1, fig. 1) agrees very well with Chun's ('98) figure, and with Moser's figure (:08b) of *amboinae*. But they vary in their precise outlines; in some of the specimens they are narrower (Plate 6, fig. 2), just as Moser (:08a) has figured them for *japonica*, and there is a series of intermediates connecting the two extremes. The differences are nothing more than contraction-phases. The precise level at which the sheaths open to the exterior is likewise a variable feature, so much so as to be worthless as a specific character unless used within broader limits than the range included in the synonyms of *palmata*. In the best preserved examples the opening is at a level varying from $\frac{2}{5}$ to $\frac{1}{2}$ the distance from funnel to apex (Plate 1, fig. 1). In *japonica* it is at about $\frac{2}{5}$; in Chun's specimen it was slightly nearer the level of the funnel.

In the flaccid specimens from Station 4600 the sheaths open higher, just as they are figured for *amboinae* (Moser, :08b, pl. 1, fig. 4); but the difference is largely due to the fact that in them, as in *amboinae*, the apex is more or less retracted by preservation. In two small specimens the level of the tentacular opening is about $\frac{2}{3}$ the distance from funnel to apex. The series shows that the differences in this respect noted by Moser are not specific.

In most of the specimens the basal ends of the sheaths fall a little short of the oral ends of the meridional canals (Plate 1, fig. 3, 6). In some, the canals extend even further beyond the sheaths, but on the other hand the sheaths in other examples are longer than the canals (Plate 1, fig. 5) as in Moser's figure of *japonica*, and in still others sheaths and canals reach about the same level, as in *amboinae* and in Chun's specimens.

The size and form of the bases of the tentacles have been used by Moser as specific characters — but both of them vary beyond the

narrow limits drawn for them by that author. In most of the specimens they reach aborally to about the level of the funnel (Plate 1, fig. 1), as in Chun's specimen. But in some they are much shorter, the precise length varying with contraction. On the other hand the tentacle-bases in flaccid specimens may surpass the funnel aborally, and extend orally almost to the ends of their sheaths: *i. e.* in examples in which the body as a whole is shrivelled or contracted and the tentacle-bases expanded, we may have precisely the characters of *amboinae*. The bases of the tentacles are usually bowed outward, *i. e.* away from the gastric cavity, at their mid-points (Plate 1, fig. 1), as figured by Moser (:08a) for *japonica*. But they vary from this condition to one in which they are practically straight (Plate 1, fig. 2): in a rather flaccid specimen 12 mm. long, only one of the bases was bowed outward, and in two of the large Japanese specimens both bases (Plate 1, fig. 6) showed the double curve figured by Chun ('98). These facts demonstrate that there is no ground for making the curve of these organs a distinguishing feature between *japonica* and *palmata*. The tentacles are contracted, but many of them still bear considerable numbers of tentilla, all of the filiform type though variously shrivelled by preservation (Plate 1, fig. 2).

An important specific character in Hormiphora is afforded by the level at which the adradial canals join the meridionals. In all the present series the junction takes place at about the level of the funnel or very slightly above it (Plate 1, figs. 1, 3), and the same is true of the specimens figured by Chun and by Moser.

Meridional canals and *paddle-ribs*. The ribs are as a rule rather shorter than the meridional canals; but the difference in length varies from practically *nil* (Plate 1, fig. 5) through a continuous series of intermediates, to a very considerable one (Plate 1, fig. 6); Chun's and Moser's figures all fall within the limits of variability of the present series; therefore the slight difference in this respect between *japonica* and *amboinae* on the one hand, and Chun's specimen of *palmata* on the other, is not specific but merely individual. It does not seem to be influenced to any great extent by contraction. The ribs, as noted by Moser (:08a) commence close to the apex, and end slightly below the oral end of the tentacular bases. As pointed out above, the ends of the meridional canals bear a similar relation to the ends of the tentacular sheaths. It is impossible to make any exact statement as to the proportional length of ribs to body as a whole, because the latter varies so much with the degree to which the mouth or pharynx is protruded or contracted. In several of the largest speci-

mens all the paddle-plates were lost, without the animals being injured in any other way. But this was, of course, accidental, as shown by a specimen in which one of the ribs had lost them all, while the others were normal.

The funnel-canal is narrow, but in contracted specimens is abnormally broad, and often folded or twisted (Plate 1, fig. 2); and this is obviously the explanation for its shortness and enlarged calibre in *amboinae* (Moser :**08b**, pl. 1, fig. 4).

Color. In life the tentacles and their bases were chrome-yellow; otherwise the animals were colorless.

BEROIDA.

BEROIDAE Eschscholtz.

Beroe Browne.

Moser (:**08a**), in her account of the Japanese Ctenophores, recognizes five species of Beroe, enlarging the list admitted by Chun ('**80**, '**98**), *i. e. ovata, forskalii,* and *cucumis,* by the rehabilitation of *clarkii* L. Agassiz, and by a new recently discovered species, *hyalina* Moser; and she has since (:**09**) described a sixth, *compacta,* from the collection of the German Antarctic expedition. Only three of these, *ovata* and *forskalii* from Naples, and *cucumis* from various localities on the east coast of North America, including Labrador and Florida, have come under my observation; they are so easily distinguished by structural characters that they are not likely to be confused.

The Beroes fall into two main divisions, according as the pharyngeal canals are simple or branched; and, as Moser points out (:**08a**), this character is a very convenient one, because the condition of the canals can usually be determined even in fragmentary specimens. The first group, with simple canals, has two members, *cucumis* and *hyalina.* The latter is distinguished, according to Moser, by its short ribs, and by the fact that the sensory body is sunken, just as it is in the cydippids, and by the unusual transparency. But the small size of the recorded specimens of *hyalina,* 11–15 mm. naturally raises the question whether these characters would be found in the adult, for, as is well known, the ribs in all Beroes are at first very short, and *ovata* and *forskalii* have simple gastric canals in early stages. It is true that Moser found genital products, but in *forskalii* at any rate these

appear long before mature size is attained. Such considerations, do not necessarily invalidate *hyalina* as a distinct species, but they certainly indicate the desirability of further study of it on more extensive material.

The second group, with branched gastric canals, includes *ovata*, *forskalii*, and *clarkii*. My own studies entirely support Chun and Moser in the view that the first two are easily separated both by general form, which is constantly different, by differences in the meridional and gastric canal-nets, and, most important, in the location of the gastric products, which are arranged in diverticula from the canals in *forskalii*, instead of in continuous bands, as in *ovata*. *B. clarkii* has recently been redescribed and figured by Moser. According to her (: **09**, p. 158), it is "kenntlich an der Form und an der charakterischen Verteilung der Rippen auf der Körperoberfläche"; that is to say, it is unusually broad, slightly constricted just above the wide mouth, and the subventral ribs are much closer together than the subtentacular, which are curved. The largest specimen was upwards of 16 mm. long, the smallest 2–3 mm. There is another recently described Beroe of the *ovata* type, *B. shakespeari* Benham (: **07**) from New Zealand, which agrees with Moser's account of *clarkii* in form, in the shortness of its ribs, and in the fact that near the aboral pole the subventral ribs lie close together. The only difference, besides size (the specimens of *shakespeari* were from 27–62 mm. high), was that in *shakespeari* the mouth was small, instead of large. But, as I have myself observed in *cucumis*, the mouth may or may not be contracted by preservation. In short, *clarkii* and *shakespeari* are undoubtedly identical, and probably represent, not a distinct species, but a variety of *ovata*, with which they agree so far as the arrangement of sex-products and branching of the canals is concerned and Mayer (: **12**) unequivocally unites them with *ovata*.

Beroe compacta is remarkable for the thickness of the gastric walls and for having very little gelatinous substance. It is so far known from one young specimen of 4 mm. only. Further details as to the canal system would be helpful. In general form it suggested a Pleurobrachia, but there was no trace of tentacular apparatus.

The genus Beroe is represented in the "Albatross" collection by only a few specimens, all small; and most of them in fragments when taken from the net. So far as I can determine all belong to *forskalii*. This is an appropriate place to record two larger *forskalii* from Fiji collected in 1897 by Mr. Agassiz. These probably were the basis for *B. australis* Agassiz and Mayer ('**99**). But the label merely gives

the locality and date, so it is impossible to be certain. *Beroe australis* has already been referred by Moser to the synonymy of *forskalii*.

Beroe forskalii Milne Edwards.

Beroe forskalii Milne Edwards, **'41**, p. 207, pl. 5 (*partim*).
For further synonymy, see Chun (**'80**) and Moser (:**09**).

Station 4654, 300–0 fathoms, 1 specimen 8 mm. long.
" 4719 300–0 " 1 " 29 mm. "
Fiji, Suva Harbor, Dec. 13, 1897, 2 specimens, 22 and 25 mm. long.
Fragments probably belonging to this species were taken at
Station 4638, 300–0 fathoms, 1 specimen.
" 4651 " " 2 "
" 4657 " " 2 "
" 4665 " " 1 "
" 4721 " " 1 "

It is noteworthy that not a single Beroe was taken in a surface haul.

The smallest specimen is at about the same stage as the 6 mm. larva figured by Moser (:**09**, pl. 2, fig. 5); the ribs now extend over the aboral $\frac{1}{3}$ of the body, and a few of the branches of the meridional canals anastomose. The gastric canals are still simple.

The specimen from Station 4719 is larger than the Fiji specimens, though younger, a discrepancy explained by different methods of preservation. The former in formalin is just the same size as it was in life, the latter, fixed with osmic acid and now in alcohol, are obviously contracted. The younger specimen already shows the flattening, somewhat pointed apex, and proportionately broad mouth characteristic of the adult *forskalii*, but the ribs, all of which are the same length, are only about half as long as the body. The meridional canals send out numerous blind branches, but only a few of them unite, so we can hardly speak of a network as yet. The gastric canals are simple through their aboral third, but oral to this they give rise to a few branches which connect with the meridional system through occasional transverse stolons. The specimens show an early stage in the formation of the sexual products, the margins of the meridional canals being slightly and irregularly lobed, even slightly beyond the extremities of the ribs. Thus, though development has progressed somewhat, the main change from the larva described above is in size and in the length of the ribs.

The Fiji specimens are much further advanced in growth. In

general form they agree very closely with adult specimens from Naples. The ribs now extend over about two thirds of the body, and none of the meridional branches anastomose. But the meridional net is still far less complete than in the adult, and the gastric net is still represented by a few branches, and occasional stolons which connect the gastric and meridional systems. The most important advance is in the sexual diverticula from the meridional canals, which have now reached practically the adult condition. It is interesting to note that the sexual lobes extend to the ends of the canals, *i. e.*, nearly to the mouth, although the paddle-ribs cover only about two thirds of the length of the canals. This, as noted above, was foreshadowed in the younger specimen. Chun ('80, p. 309) says that the formation of sexual products ceases at the ends of the ribs; but this statement is true only in the adult, where the ribs extend over four fifths or more of the length of the canals.

Beroe forskalii has been recorded from Fiji, from the coast of California, and from various localities among the Malay Islands; and the present captures show that it is widely distributed, though apparently not very common, in the eastern part of the Tropical Pacific. It is also recorded by Maas (: 08) from the Antarctic. Although his material was not in the best of condition, it showed clearly that the gastric canals were branched, a fact separating it definitely from *B. cucumis*, which is the representative of the genus which might have been expected in that region. The specimens likewise agreed with *forskalii* in form, but it is better not to lay too much stress on this character in preserved specimens. Unfortunately Maas could not determine the arrangement of the gonads, which is the most important feature separating *forskalii* from *ovata*. A fresh examination of the Beroes of the Antarctic would be valuable, because apart from this one record, *B. forskalii* is known only from warm and temperate regions.

Pandora Eschscholtz.

The genus Pandora, merged with Beroe by Chun and by Mayer (: 12), has been reinstated by Moser, to include those species which agree with Beroe in anatomy, but in which the ribs are of unequal length. This difference is, of course, a slight one. But the diversity in the length of canals, in forms in which it occurs, is present in the earliest stages in which any of them are known, while, on the other hand, all the ribs in Beroe are nearly or quite of one length from the

beginning. Furthermore, each type of rib characterizes several species; and no form is yet known intermediate between the two For these reasons Pandora seems worthy of generic rank. The genus is especially interesting because it may afford a case of "dissogonie" in the cases of *P. pandorina* Moser and of *P. flemmingi* Eschscholtz. Moser (:**03**, p. 26) has given a thorough discussion of these two species, pointing out the possibility that they may belong to a single developmental series. Briefly stated, the difference between the two is that *pandorina* is small, with very large stiff cilia about the mouth, and sexually mature, while *flemmingi* is much larger (up to 25 mm. high) with small, slender lip-cilia, and not mature even at this large size. No intermediates have yet been found, and it is to be hoped that some student will shortly have access to more complete series of the two.

P. mitrata Moser (:**08a**) from Japan differs from *P. flemmingi* in being cylindrical when adult, and in the fact that the branches of the meridional canals run toward the mouth and anastomose much less often than they do in *flemmingi*. According to Moser its gastric cilia are unusually thick and long, as in *P. pandorina*. The "Albatross" collection contains a single specimen which agrees very closely with Moser's figure and descriptions of *mitrata*.

The *Beroe punctata* of Chamisso and Eysenhardt is also included in Pandora, by Moser (:**08a**) on the strength of Eschscholtz's statement that its ribs were of unequal lengths. No unquestioned record of it has since been obtained. Until it is redescribed it must remain on the doubtful list.

Pandora mitrata Moser.

Pandora mitrata Moser :**07**, p. 451, :**08a**, p. 34, taf. 1, fig. 1–3; :**09**, p. 159.

Station 4727, surface, one specimen, 16 mm. high, in good condition.

The single example agrees so well with Moser's figures that a detailed account is unnecessary. The ribs are slightly longer, the subventral extending over about two thirds, the subtentacular over slightly less than one half of the body; but the mouth-region is somewhat contracted, so it is positive that the discrepancy is to be explained at least partially by preservation. The branches of the meridional canals are mostly blind, and all run toward the mouth, exactly as Moser figures them, and the gastric canals are unbranched.

Corresponding to the flattening of the body, the subventral ribs of each pair lie close together, the subtentacular further apart. The sexual products occupy the meridional canals only so far as the ends of the ribs, and where they occur the margins of the canals are very slightly lobed. In Moser's specimens the cilia of the stomach agree with those of *P. pandorina, i. e.,* they are unusually stout and long, and there was no "Wimperschnur um den Mund." So far as I can judge from surface views with the microscope, the conditions are the same in the "Albatross" specimens. Certainly there is no visible band of cilia surrounding the mouth; and wherever a few gastric cilia can be distinguished they are remarkably stout. But for the most part they are gone.

To judge from the three records of this species, Japan (Moser), west coast of South Africa (Moser), and the Eastern Tropical Pacific, it is very constant in character. All the older specimens agree in having unequal ribs, and in their arrangement in pairs, in general form and proportions, in having a large mouth, in the type of branching of the meridional, and simplicity of the gastric canals; and in the limitation of the sexual products to the portions of the canals occupied by the ribs. The present capture is interesting from the standpoint of geographical distribution, as showing its wide dispersal over the Pacific, and that it occurs there on both sides of the Equator. In the Atlantic it is so far known only from lat. 32° 5′ S., long. 8° 30′ W.; between Ascension and St. Helena, and from near Cape Town (Moser, :09). But its general resemblance to a Beroe is so great that it might easily be overlooked by anyone but a specialist.

LOBATA.

BOLINOPSIDAE nom. nov.

Bolinopsis L. Agassiz.

While the "Albatross" lay at anchor in Acapulco Harbor I was able to study, in life, a large and beautiful Bolinopsis,[1] of which several specimens were taken. Moser has recently attempted a revision of this genus, and done much to bring order out of confusion, though the relationships of the several forms recorded from tropical regions are

[1] Bolina is preoccupied for a mollusc (Mayer, :12, p. 20).

still unsettled. Moser agrees with Vanhöffen ('95) that the north Atlantic *infundibulum* and *alata*, and the Behring Sea *septentrionalis* all belong to one species of circumpolar distribution. This view seems to me thoroughly in accord with the various published figures and descriptions, and my own studies of living specimens from the coasts of New England lead me to adopt it without hesitation. The best figures of the New England form are those by L. Agassiz ('49); of the north European by Vogt ('88). *B. infundibulum* is the only species which is known from more than very few records; and even for it the normal limits of variation are still to be traced. Under these circumstances it is very difficult, perhaps impossible, to reach a sound conclusion as to the relationships of the various other species.

The following are listed by Moser (:08a): — *hydatina* Chun from the Mediterranean, *elegans* Mertens from the "South Seas," *chuni* von Lendenfeld from south Australia, *vitrea* L. Agassiz ('60) from the southeastern coasts of the United States, *ovalis* Bigelow (:04) from the Maldive Islands and *mikado* Moser (:07, :08a) from Japan. And to show how little we know about them, I may point out that *ovalis* and *mikado* were each described from a single fragmentary specimen, *elegans* from a single record in 1827, and *vitrea* from very few records.

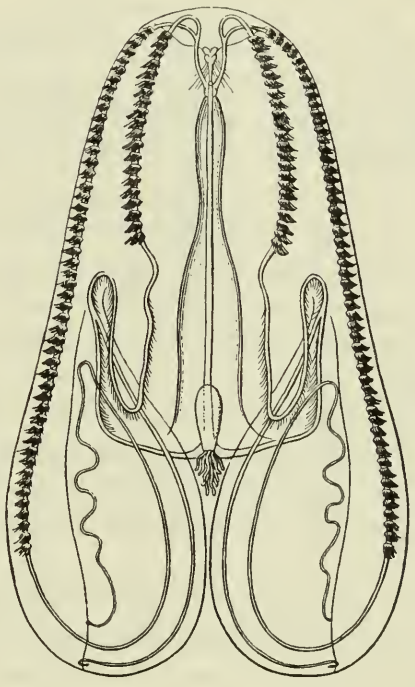

Fig. A. *Bolina vitrea*. Specimen from Acapulco, 82 mm. long. After a drawing from life. The musculature of the inner surface of the lappets is omitted.

The Acapulco specimens agree most closely with the accounts of *vitrea*, and particularly with Mayer's figures of that species. Like the latter they are comparatively slender in outline, the lappet-canals are but little convoluted, and the auricles are short. The only differences are that in our largest specimen (82 mm. long) the lappets are proportionately slightly shorter than Mayer shows them, that the subventral ribs extend further over the lappets (Fig. A), and that the canals and tentacular apparatus were amber-yellow instead of being

colorless, or pink. But observation of the living specimens showed that the proportional length of stomach to lappets may change through wide limits from moment to moment as the animal contracts and expands. In a specimen 69 mm. long, at rest the proportion was almost exactly what A. Agassiz shows ('65, fig. 19). The slight difference in the length of the ribs may be nothing but a growth character at any rate it is too slight to be used as the basis for specific separation. There remains, then, only the question of color; and until the Pacific form is known from more than one locality, the importance of this must remain in doubt. It may be nothing more than a temporary physiological phenomenon controlled by food; and this would be the natural explanation did the canals alone show it, but the yellow color of the tentacular apparatus may be more significant. *B. vitrea* is described by A. Agassiz as wholly colorless. Two courses are open; to refer the specimens provisionally to *vitrea,* or to institute for them a new variety of the latter; the former will most satisfactorily express our present scanty knowledge.

One can not compare the Acapulco specimens with my (: 04) figure of *ovalis* without being struck by the likeness between the two; indeed the only apparent difference is that the latter, like *vitrea,* is colorless. My only reason for separating it from the latter was that the lobes were proportionately longer, the stomach shorter. Unfortunately the single specimen of *ovalis* was two fragmentary for accurate diagnosis. But its obvious resemblance to *vitrea* suggests at least the possibility that some variety of the latter will be found to be at home in the tropical and subtropical waters of all three great oceans.

A comparison between *vitrea* and *hydatina* shows that the two are closely allied in structural characters, *i. e.* they agree in the simplicity of the lappet-canals and short auricles. But to judge from Chun's figure ('80, taf. 4, fig. 5) the Mediterranean form is shorter, broader, and less flattened than *vitrea,* and the ribs are rather shorter. We have no account of the final stage in growth; the largest specimens observed by Chun being only 4 mm. long; *vitrea* attains a length of upwards of 70 mm. It may be that the differences in external form are growth characters, and that such is the case is suggested by the fact that I have compared small specimens from Acapulco with corresponding stages of *hydatina* from Naples, without finding a single character to separate the two. But it is hardly worth while to speculate further along this line until living or well preserved adult specimens from the Mediterranean are examined. I believe, however,

that we can safely say that the closest relationship of *hydatina* is with *vitrea*, not with *infundibulum* as Mayer (:**12**) supposes.

Bolinopsis mikado, likewise, has short auricles and simple lappet-canals so far as the latter could be traced, but the sense-body is much more deeply sunken than in any other Bolinopsis; and the structure of the ribs further differentiates it. It is highly desirable that better material of this interesting species be studied. The same is true also of *elegans*, which is characterized, according to Mertens, by the presence of numerous papillae on the outer surface of the body, lacking in other species of Bolinopsis.

Bolinopsis chuni has been described in detail by Lendenfeld: its distinguishing features, as noted by Moser (:**08a**, p. 56), are the extraordinary thickness of the lappets, the simplicity of the lappet-canals, and by the fact that the gastric canals lie at some distance from the stomach.

Bolinopsis vitrea (L. Agassiz). Mayer.

Bolina vitrea L. Agassiz, '**60**, p. 269, 289, fig. 93; A. Agassiz, '**65**, p. 19, fig. 19; Mayer, :**00**, p. 81, pl. 27, figs. 91, 92; Moser, :**08a**, p. 53.

Bolinopsis vitrea Mayer, :**12**., p. 22, pl. 5, fig. 16–19.

Acapulco Harbor, 4 specimens, 10–82 mm. long.

Unfortunately I was unable to preserve any specimens. Although I tried various preservatives and various methods of stupefaction, all the bottles were found after the journey across the continent to contain nothing but a gelatinous mass of fragments. But as I foresaw from my experiences with *B. infundibulum* that this might happen, detailed drawings and notes were made from life, and the following account is based upon these.

1. *Adult.* Two large specimens, 82 and 69 mm. long, were taken and kept under observation for several hours. The largest, when at rest (Fig. A), lay with the lappets touching. In this position its longest diameter at the level of the top of the auricles was slightly half its length; and the lappets extended beyond the mouth for a distance equal to about $\frac{3}{8}$ of the length of mouth-pole. That is to say, the stomach was comparatively long. The auricles are short: they arise at the mid-level of the stomach, and do not quite reach the mouth, thus bearing the same relation to the gastric system that they do in

the Mediterranean *hydatina*. The ribs are, of course, unequal, the subgastric being very long, and extending over more than half the length of the lappets. And the paddle-plates are very numerous.

The course of the canals over the lappets is interesting, and was easily traced. The upper, *i. e.* pharyngeal, loop is more easily understood from the figure (Fig. A) than from a verbal description. It is much less complex than in *infundibulum*. In the latter, according to the descriptions of L. and of A. Agassiz the transverse trunk which connects the loop on either side is bowed in the middle in a pronounced double curve. But in the present specimen it is nearly direct, there being merely a slight curve in the mid-line. The descending branches of its two lateral loops are thrown into a series of small curves, but these vary in number on the two sides, and became more or less pronounced according as the animal expanded or contracted. In general the canals agree with those of Mayer's specimens. As in the other species the inner surfaces of the lappets are provided with a well-developed musculature of crossed fibres.

The funnel-canal is very short, and the adradial canals empty directly into the ends of the meridionals. The tentacular apparatus is of the usual bolinid type. The specimen of 69 mm. is proportionately broader than the one just described, and its lappets are longer, extending beyond the mouth for a distance equal to two thirds the polar length of the animal. That is to say, this specimen agrees very well in its proportions with Mayer's figures. Furthermore the auricles as in the latter, hung just beyond the mouth. When the animal contracted transversely with the folding of the lappets, it became elongated, and the stomach proportionately longer than when at rest. The course of the canals was the same as in the larger example, except for minor variations in the convolutions, which were less pronounced. It is evident, then, that the external proportions differ considerably at different stages in growth, or that they vary individually.

Two young specimens of Bolinopsis were taken. In the younger, 10 mm. long, the lappets have just appeared, but are still very short. In this respect the specimens agree with the young *infundibulum* shown by A. Agassiz ('65). But in other respects they are much further advanced, the ribs being longer, already with twelve paddle-plates in each of the tentacular, sixteen or seventeen in the pharyngeal; the stomach laterally flattened and of the adult triangular form, the lappet-canals, both inner and outer, complete, and the tentacular sheaths opening well below the level of the funnel, about mid-way between it and the mouth-level. No trace of the auricles is yet to be seen.

In an older stage of 20 mm. very similar to one shown by Mayer (:12, pl. 5, fig. 19) the lappets have grown longer, the lappet-canals already show the main loops of the adult, the tentacles now open at about the level of the mouth, though their canals still lie far from the oesophagus, and the young auricles are visible. The only apparent difference between these specimens and *infundibulum* of corresponding ages is that in the former the auricles appear before the lappet-canals are fully formed, whereas in the latter the reverse is the case.

CESTIDA.

CESTIDAE Gegenbaur.

Cestum Lesueur.

Up to the present time two species of Cestum have been described from the Pacific, *C. najadis* Eschscholtz, and *C. amphitrites* Mertens; but of neither is the status satisfactorily determined. *Cestum najadis* is distinguished from the Atlantic *veneris* by its possession of long tentacles of the cydippid type; and, according to Moser (:08a, p. 13), by its geographical occurrence. The latter reason can not be abandoned too soon, as I have already pointed out (:09) for similar cases among Medusae; but the former is of real value, if it can be depended upon. Unfortunately the animal is known from the original description only. And it would be so remarkable for a cestid to have long tentacles, that we may be pardoned if we hesitate to accept the account until it is verified. There is another difference between *najadis* and *veneris* which has not been emphasized previously, namely that the tentacle-bases are yellow in the former, colorless in the latter. In this respect *najadis* agrees with *amphitrites*, but here again we are confronted by the question of the structure of its tentacles.

Cestum amphitrites was so beautifully figured by Mertens ('33) that we can gain a very good idea both of its anatomy and of its general appearance in life. Color proves a very obvious difference between it and *veneris*, for whereas the latter is colorless, the tentacular bases of the former are brownish yellow, and there is a spot of the same color at either extremity of the band-like body. Anatomical differences were thought to exist by Mertens ('33, p. 493) namely the presence of "zwei Blättchen die das Stigma. . . . einfassen" and of "zwei bandförmige Kanten. . . . die an beiden Flächen, der oberen wie der untern,

durch die ganze Ausdehnung des Thieres verlaufen." But the first of these seem to be nothing but the rounded gelatinous prominences which Chun has figured for *veneris* ('80, taf. 13, fig. 4). And as for the latter, I can find nothing in Mertens's figure which I can thus identify, and therefore am in some doubt as to just what was meant.

The only structural feature which may separate *amphitrites* from the Atlantic form is a slight apparent difference in the relations of adradial to meridional canals. But Mertens's figure ('33, pl. 1, fig. 5) is obviously somewhat diagrammatic, and not altogether clear. I have considered *amphitrites* thus fully because a single Cestum was taken which agrees with Mertens's figure in color, as well as in its general form and structure, and which may therefore be identified safely as *amphitrites*. Anatomically I was able to find nothing to differentiate it from *veneris*: it agrees even in the proportions of the various organs and canals; but unfortunately parts of the canals were destroyed.

Whether *najadis* can be referred to *amphitrites*, as its color suggests, is doubtful, as pointed out above. There is one other Cestum the color of which suggests that it probably does belong there, namely *C. pectenalis* Bigelow from the Maldives. Moser (: 08a) has pointed out that my description of that species was unsatisfactory; and I can go farther and say that the account, my first attempt at zoölogical description, was founded on insufficient notes, and is therefore practically worthless. I have recently referred to my original drawings (no specimens were preserved) and would state that the only details which can be depended on are the general form and the yellow spots at either extremity.

Cestum amphitrites Mertens.

Cestum amphitrites Mertens, '33, p. 492, taf. 0; L. Agassiz, '60, p. 291.

Cestus veneris Chun, '80, p. 301 (partim).

Cestus amphitrites Moser, : 08a, p. 14.

?*Cestus pectenalis* Bigelow, : 04, p. 267, pl. 8, fig. 30.

Station 4546 Hyd. (14° 50′ N. lat., 101° 31′ W. long.).

One specimen, about 60 cm. long was taken, and several others were floating on the surface.

The specimen was in good condition, except for some damage to the canals, and was kept under observation alive for some

time. It was then preserved in formalin, but fell into fragments during the journey home. So far as its general anatomy is concerned it agrees very well with a somewhat smaller specimen of *veneris* from Naples, with which I have compared it. The polar length, in life, was about 45 mm., and the body tapered gradually to the extremities, which were rounded, as in *veneris*. The only noticeable difference in form is that the oral margin of the band-like body is about as broad as the aboral margin. In *veneris* it is much narrower, so that a cross-section, taken at either side of the stomach is roughly triangular (Chun, '80, taf. 13, fig. 3). In the present specimen such a cross-section would be roughly rectangular. But in both, the body is broadest along the lines of the subtentacular meridional canal.

The subgastric ribs closely resemble those of *veneris*, the paddle-plates being closely crowded and very numerous, and sexual products were visible for the entire length of the subventral meridional canals. I could not determine definitely whether or not there were any paddle-plates in the subtentacular canals, as the critical region was damaged; but there were four agglutinated masses of cilia which lay in positions corresponding to the subtentacular plates of *veneris*, and they should probably be identified with the latter. The stomach was about 32 mm. long, the funnel-canal only about 6 mm.; the proportions between the two thus being about the same as they are in *veneris*. The junction of adradial with meridional canals could not be traced.

Tentacles. The tentacles, as in *veneris*, lack axial filaments, and consist of a large number of filiform tentilla arising from the swollen base. The tentacular sheaths are about one half as long as the polar length. The "Tentakelrinne" bear filamentous tentilla throughout their length.

The most striking specific character of *amphitrites* is its color. The tentacle-bases are chrome to amber-yellow; the subtentacular meridional canals show as lines of the same color throughout their length; and at each extremity there is a spot of somewhat darker yellow. These spots were common to all the specimens we saw, making them very conspicuous in the water. But though so noticeable, they, and the color-bands along the meridional canals, have disappeared with preservation, the yellow tint of the tentacles alone persisting.

GEOGRAPHICAL DISTRIBUTION.

Moser's (:09) recent discussion of the geographical distribution of the Ctenophores is so thorough that it will no doubt form the starting point for all future work along this line, and Mayer (:12) has given a valuable account of the occurrence of the group on the east coast of North America. But inasmuch as the Eastern Tropical Pacific, so far as its Ctenophores are concerned, was practically a blank on the map, until visited by the "Albatross," our records are of considerable importance in their relation to Moser's general conclusions. They help to fill in a very large geographic gap. There were only two species, viz., *Hormiphora palmata* and *Beroe forskalii*, which occurred often enough to show the regularity of their distribution within the area examined. The former was taken on all our lines, and its occurrences (Plate 2) were sufficiently numerous to show that it is a characteristic and typical member of the pelagic fauna of the Eastern Tropical Pacific. It is noteworthy that it was not encountered in the colder waters of the Humboldt Current close to the Peruvian coast, on either of our two southern lines. This may have been a coincidence; indeed, equally broad gaps may be seen on other lines. But it is an interesting fact that it was not the only common surface form found on all our lines, but absent from the cold-coast water traversed on the two southern sections of the Humboldt Current. Practically the same distribution was true of several Siphonophores (Bigelow, :11).

Moser's record of *H. palmata* (= "*japonica*") from Japan is especially interesting because so far as the locality, Sagami Bay, shows, it might belong to either the cold- or the warm-water fauna. The oceanographic conditions along the east coast of Japan have been explained in a very lucid way by Doflein (:06), who himself noticed a startlingly rapid and complete change in the surface fauna in Sagami Bay from days when the warm waters (22–24° C.) of the Kuroshiwo Current swept into it, to others when they were replaced by cold water (15–18° C.) after north and northwest winds. In the former case he collected a typical tropical fauna, including such genera as Cestum, Porpita, Forskalea, Physalia, Janthina, Philliroe, and Carinaria. In the latter these were entirely lacking and in their places were found northern copepods and diatoms.

Now, in turning to Moser's (:08a) list of Japanese Ctenophores collected by Doflein, we find that Cestum was taken at the same locality, and on the same date as Hormiphora. And the "Albatross"

captures in Japanese waters were all from temperatures above 72° F. For these reasons, and because all other records of *H. palmata* or of the forms so closely allied to it that I regard them as synonyms, are from temperatures above 21° C., we can safely conclude that this species is brought to the coast of Japan by the warm water of the Kuroshiwo Current. On the west coast of America, the "Albatross" records carry *H. palmata* as far north as lat. 20°; but it is probable, though not absolutely certain, that this species was taken at San Diego by Torrey (p. 380). Judging from surface temperatures, it might have been expected to occur perhaps as far north as Santa Barbara Channel where the first noticeable admixture of northern coelenterates has been observed (Fewkes, '89). But it was not found in San Francisco Bay by A. Agassiz, who would hardly have overlooked it had it been a characteristic member of the surface fauna in that region. And, from the standpoint of temperature, we would hardly expect a tropical form to occur there.

The genus Hormiphora, except for *H. cucumis*, is confined to tropical and subtropical waters so far as the records yet show. The coldest record for any recent specimen is 64° F.; in the case of one *H. ochracea* taken by the "Albatross" in 1900, lat. 31° 10′ N., long. 125 W., but *cucumis* is known from off the coast of Alaska, between Sitka and Unalaska, in a temperature of about 45°. It is not likely that so conspicuous a form would have escaped notice, did it occur in the temperate or colder parts of the Atlantic, for example the Labrador Current, the North Sea, the northern coast of Europe, or in New England waters.

Beroe forskalii was not taken so often as Hormiphora, but the position of occurrence, together with the previous records from the coasts of southern California, from Fiji, from the Ellice Islands, Hawaii, the Malay Islands, and the Maldives, show that it is very generally distributed over the tropical Indo-Pacific, as it is in the Atlantic. This species is not known from cold currents in the Atlantic, though as I have pointed out above (p. 388), it is recorded from the Antarctic.

Another form which is so far known from warm regions only is *Bolina vitrea*. Up to the present time this species, whose validity seems assured, was known only from the southeastern shores of the United States. But the "Albatross" records show that it also occurs in the Tropical Pacific; and it is probably recorded from the Indian Ocean (p. 392). The captures of Pandora extends the range of that form to the Eastern Tropical Pacific. Discovered in Japan only

six years ago, Moser (: 09) has already recorded it from the tropical Atlantic, the south Atlantic, and the neighborhood of Cape Town. And it is not only the wide separation of these localities which is striking, but the fact that the few records yet obtained already extend its temperature range from 58.6° F. to 79° F. is even more important as showing over how broad a range it may be expected. I may likewise emphasize the occurrence of *Pleurobrachia pileus* in Acapulco Harbor, at a temperature of 83° F. Moser (: 09) speaks of this species as a northern form, and uses this as an argument against uniting Graeffe's Pleurobrachia from Trieste with it. When a species occurs from the Arctic to lat. 34° N. in the north Atlantic; along the west coast of America from Puget Sound to Acapulco, at the Seychelles; at various South African localities, and very generally in the Antarctic; when it thus runs through the entire gamut of oceanic temperatures, it would not be surprising to find it anywhere. And, as a matter of fact, it does occur in the Mediterranean (p. 372). It is truly cosmopolitan, as it is classified in Moser's list. But though its range reaches from pole to pole, it is a much more important constituent of the Arctic and Subarctic than of the tropical plankton. In the colder Atlantic currents it is regular in occurrence, and often extremely numerous; in the tropics it is recorded only occasionally, and usually from small specimens.

The "Albatross" discovered no local species of Ctenophores. All her captures extend the range of previously known forms, but they afford some evidence that at least one genus, Cestum, has one tropical species in the Indo-Pacific, another in the Atlantic; though the case is not yet altogether clear. There is no evident reason why this should be the case, when one species of Hormiphora extends over both oceans, but I may point out that there is an Atlantic and a Pacific species of Physalia, of Porpita, and probably of Velella, whereas most tropical Siphonophores are cosmopolitan in waters of suitable temperatures.

To sum up:— the "Albatross" collection lends important support to Moser's generalization that the Ctenophores as a whole are animals of wide distribution; and it reduces by one, *Pleurobrachia rhodopsis*, the list of forms so far known only from restricted localities. It also rescues from obscurity one of the old species, *Cestum amphitrides* Mertens.

In the accompanying map (Plate 2) the occurrence of Ctenophores is plotted for the eastern half of the Pacific, only records of the specific identity of which there is no reasonable doubt being included. For

the various doubtful forms, see Moser (:**09**). To illustrate how nearly virgin the region previously was, I may point out that of the forty-eight records all but eleven (Moser, :**09**, taf. 22) are from the collections of the "Albatross"; and only three were previously made in the oceanic quadrangle where the "Albatross" did her actual work in 1904–1905; *i. e.*, from about 20° N. to 24° S.; and from 80° W. to 135° W.

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PLATE 1.

Hormiphora palmata.

Fig. 1. Side view of specimen 24 mm. long, in tentacular plane, with the pharyngeal rows of paddle-plates dissected away to show internal anatomy.

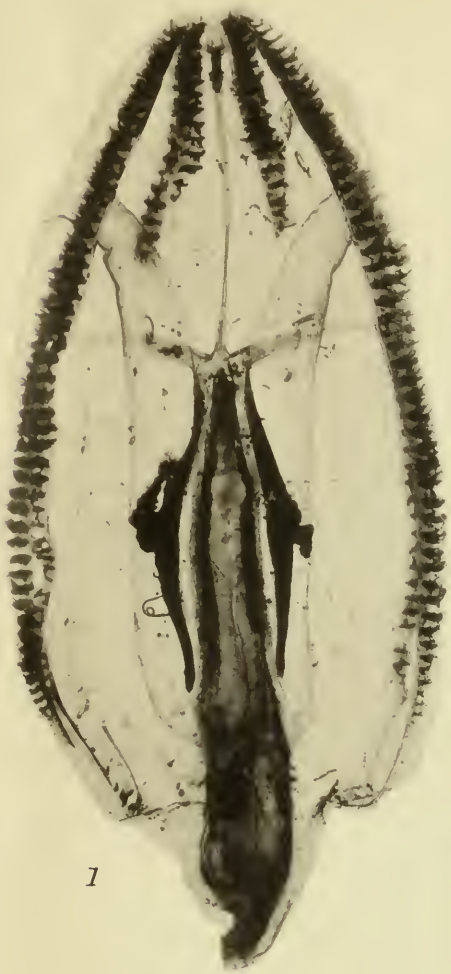
Fig. 2. Side view in tentacular plane of somewhat contracted specimen 18 mm. long, similarly dissected.

Fig. 3. Side view in pharyngeal plane of specimen 24 mm. long.

Fig. 4. Portion of specimen 28 mm. long, from Japan, to show the form of the bases of the tentacles.

Fig. 5. Pharyngeal view of oral portion of specimen in fig. 2, to show the relative lengths of ribs, meridional canals, and tentacular sheaths.

Fig. 6. Similar view of specimen shown in fig. 3.



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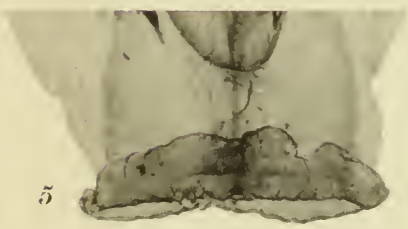

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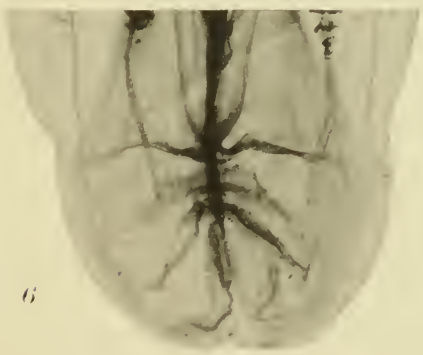

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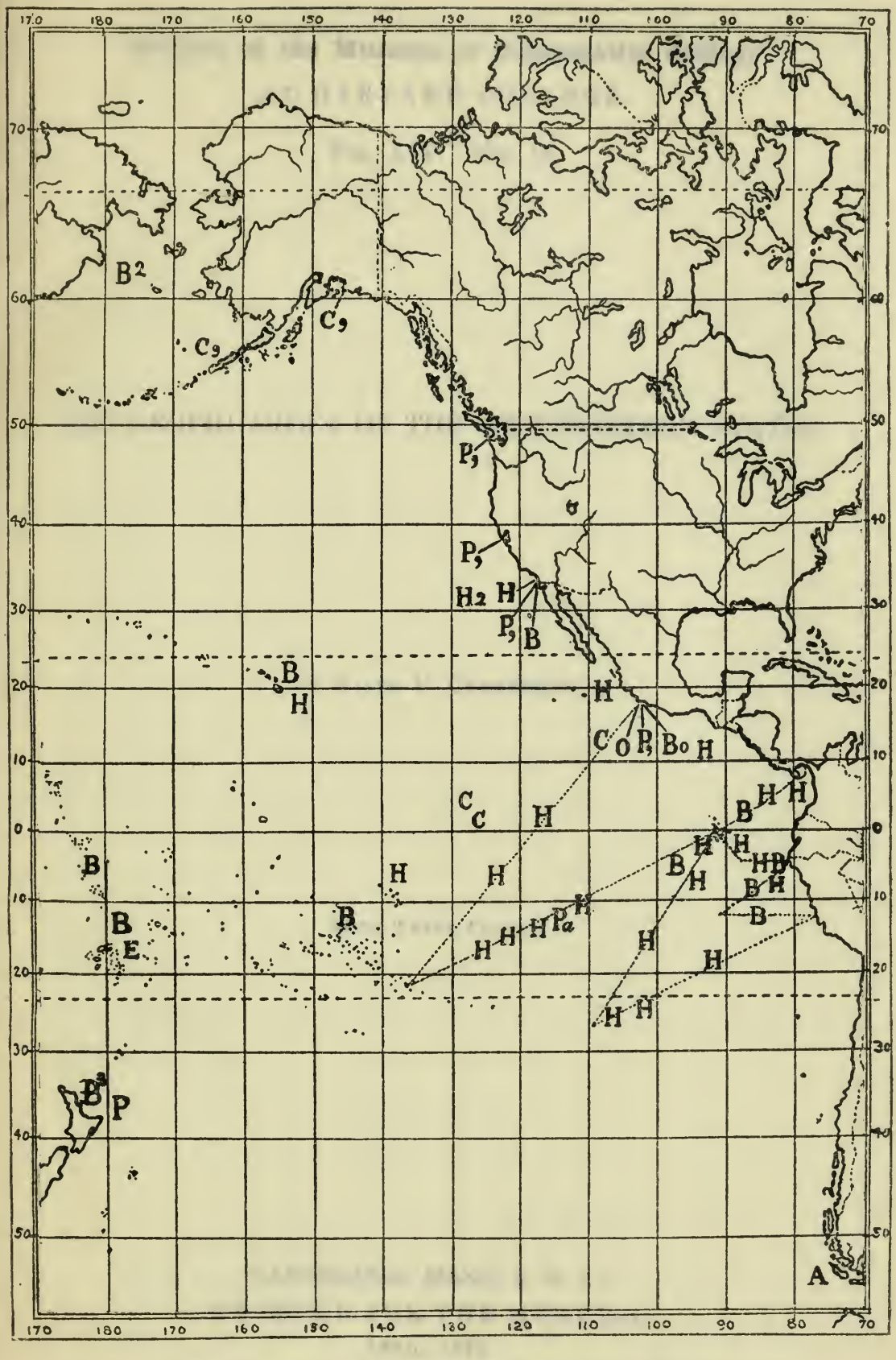
H. E. B. PHOTO. HELIOTYPE CO., BOSTON

PLATE 2.

Chart of the eastern part of the Pacific, showing records of Ctenophores. The dotted line is the course of the "Albatross," 1904–1905. Only records of well-established identity are included.

A = Calliarina antarctica.
B = Beroe forskalii.
B^2 = Bolinopsis septentrionalis.
B^3 = Beroe clarkii.
B^0 = Bolinopsis vitrea.
C = Cestum.
C, = Hormiphora cucumis.
E = Eucharis.
H = Hormiphora palmata.
H^2 = Hormiphora ochracea.
P = Pleurobrachia pileus.
P, = Pleurobrachia pileus var. bachei.
Pa = Pandora mitrata.



Distribution of Ctenophores in Eastern Pacific.