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the tide of Mahometan conquests as effectually as it was arrested for Western Europe by Charles Martel on the plain of Tours. They saved the Italian and perhaps even the Teutonic and the Scandinavian lands from a tyranny which has blasted the fairest regions of the earth; and if they added fuel to the flame of theological hatred between the Orthodox and the Latin churches, if they intensified the feelings of suspicion and dislike between the Eastern and the Western Christians, they yet opened the way for an interchange of thought and learning which had its result in the revival of letters and in the religious reformation which followed that revival. If, again, of their leaders some showed themselves men of merciless cruelty and insatiable greed, there were others who like Tancred approached the ideal of the knightly chivalry of a later generation, and others again whose self-sacrifice, charity, and heroic patience furnish an example for all time. The ulterior results of the crusades were the breaking up of the feudal system, the abolition of serfdom, the supremacy of a common law over the independent jurisdiction of chiefs who claimed the right of private wars; and if for the time they led to deeds of iniquity which it would be monstrous even to palliate, it must yet be admitted that in their influence on later ages the evil has been assuredly outweighed by the good.

Gibbon, *History of the Decline and Fall of the Roman Empire;* Michaud, *Histoire des Croisades;* Mills, *History of the Crusades;* William of Malmesbury; Joinville, *Memoirs of the Crusades of St Louis;* Richard of Devizes; Geoffrey of Vinsauf; Geoffrey of Villehardouin; Wilken, *Geschichte der Kreuzzüge;* Haken, *Gemälde der Kruezzüge;* Milman, *Latin Christianity,* book vii. ch. vi.; Hallam, *Middle Ages,* ch. i. part 1.; Mainbourg, *Histoire des Croisades;* Finlay, *History of the Byzantine and Greek Empires, from* 1057 *to* 1453; James de Vitry, *Historia Orientalis;* Choiseul d'Aillecourt, *Mémoires sur les Croisades;* Heeren, *Essay on the Influence of the Crusades.* (G. W. C.)

CRUSENSTOLPE, MAGNUS JAKOB, a Swedish historian, was born in 1795. He became early famous both as a political and an historical writer. His first important work was a *History of the Early Years of the Life of King Gustavus IV. Adolphus,* which was followed by a series of monographs and by some politico-historical novels, of which *The House of Holstein-Gottorp in Sweden* is considered the best. He obtained a great personal influence over King Karl Johan, who during the years 1830–33 gave him his fullest confidence, and sanctioned the official character of Crusenstolpe's newspaper *Fäderneslandet.* In the last-mentioned year, however, the historian suddenly became the king's bitterest enemy, and used his acrid pen on all occasions in attacking him. In 1838 he was condemned, for one of these angry utterances, to be imprisoned three years in the castle of Waxholm. He continued his literary labours until his death in 1865. Few Swedish writers have wielded so pure and so incisive a style as Crusenstolpe, and it is by virtue of the elegance of his writings that he will survive, for his historical worth is injured by the passionate bias of his political and personal antipathies.

CRUSIUS, CHRISTIAN AUGUST (1715–1775), after Buddæus the most distinguished theological opponent of the Wolfian philosophy and critical methods, was born on the 10th of January 1715, at Leuna, in Merseburg, a division of Prussian Saxony, and passed to the university of Leipsic in 1734. After attending the usual classes, he became extraordinary professor of philosophy in Leipsic in 1744, professor of theology in 1750, and theological principal in 1755. He died on the 18th of October 1775. Two of the great objects of his life were to place philosophy on a thoroughly satisfactory basis for the future, and to bring philosophical conclusions into harmony with orthodox theology. The university was divided by the disputes that were rife into two parties—the "Ernestianer" and the "Crusianer." The former contended for a purely grammatical interpretation of Scripture, and carried out their theory to its logical consequences. They thus subjected the sacred writings to the same laws of exposition as are applied to other ancient books. Ernesti, adopting the principles he had employed in dealing with the classics, looked at the Bible from a purely philological stand-point. Crusius, on the other hand, explained Scripture in the light of the labours of the church and the usually received theological system. This had great influence on his philosophical position. He had inherited a bias against the Wolfian views from his teacher Rüdiger; and numerous works were issued by him on logic, metaphysics, psychology, and moral philosophy—all with a direct controversial bearing. The system of Crusius was not successful, but it had a few very enthusiastic supporters. His mysticism and sincere religious spirit endeared him to the Pietists and the followers of Zinzendorf, who would naturally regard him as an able opponent of the extreme rationalizing tendencies (Aufklärung) of the time. His views of prophecy, too, and of its important connection with the Christian economy, had considerable influence on Hengstenberg and Delitzsch. The principal works of Crusius are *Hypomnemata ad theologiam propheticam* and his *Moral Theology.* The latter is in two parts. In the first, taking revelation as his starting point, he combats the Wolfian idea of human perfection, and treats of the depravity, conversion, and sanctification of man. He seems to have held, like Dr Wardlaw, that natural, as distinguished from Christian, ethics are not legitimate. The second part is devoted more specially to morals. The book, although prolix, is animated by genuine religious feeling. Although Crusius had great influence on many of his contemporaries, he unfortunately outlived his reputation. He was a profound, subtle, and original thinker, and was, perhaps, drawn into mysticism by his attempts to reconcile theology and philosophy. His works have fallen into the background; but he is still remembered for his profound learning, unfeigned piety, and purity and earnestness of character. Few controversialists have left behind them so stainless a name.

CRUSTACEA

THERE is probably no class among the Invertebrata which offers so many striking family and individual peculiarities as are to be met with among the Crustacea. Having a special type of structure, and possessed of numerous characteristics in common, they nevertheless put on such diverse appearances both in the young and adult stages of their existence as frequently to have baffled the most able investigators, whilst many of the vagrant members of the class still challenge further research.

The masterly and exhaustive labours of Charles Darwin on the Cirripedia have rescued that aberrant group from obscurity, and many of the parasitic forms have been relegated to the various orders of which they are in reality only degenerated members, their organs having suffered atrophy, and frequently their entire structure having undergone modification, in consequence of the peculiar existences which they lead. But our advance towards a more correct knowledge of the class, as a whole, has been mainly derived from the accumulated store of embryological and developmental studies which—commenced in 1823 by Vaughan Thompson—have in these later years been so successfully prosecuted by Audouin and Milne-Edwards, Darwin, Spence Bate, Van Beneden, Claus, Anton Dohrn, A. S. Packard, O. F. Müller, Fritz Müller, and very many other naturalists. Much, however, still remains to be accomplished.

The CRUSTACEA belong to the sub-kingdom ANNULOSA, and to the division ARTHROPODA, in which are also included the INSECTA, the MYRIAPODA, and the ARACHNIDA; they are known also as ARTICULATA, from the body being composed of a series of distinct rings or segments, each segment usually possessing a pair of jointed appendages or limbs articulated to it. They may be defined to be those Articulata which, whenever respiratory organs are specially developed, possess branchiæ and not tracheæ. By this definition they are at once separated from all insects and myriapods, which invariably possess tracheæ. But it remains a difficulty, if it be not altogether impossible in the present state of science, to frame any definition which shall similarly include all CRUSTACEA and exclude all ARACHNIDA. In both classes, in fact, there are forms which possess no special respiratory organs; and if in these cases we resort to other characters, none which are of universal application have as yet been discovered.

It may be said, however, that as a rule these exceptional Crustacea possess more than four pairs of locomotive appendages, have two pairs of antennary organs, and possess a simple alimentary canal; while the Arachnida generally have not more than four pairs of locomotive appendages, possess at most one pair of antennary organs, and have their alimentary canal produced into cœca (Huxley).

EXTERNAL STRUCTURE.—The skin of the Crustacea is more or less completely hardened by a horny deposit

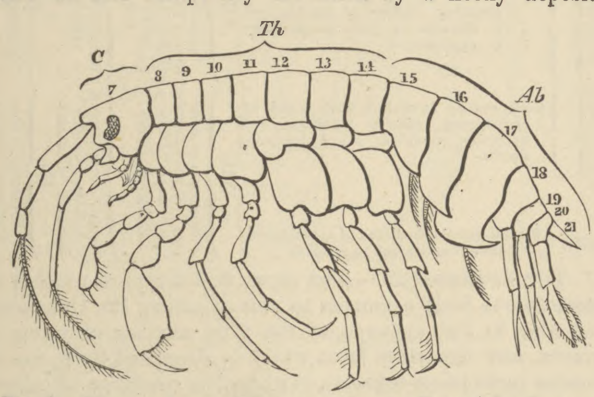


FIG. 1.—Diagram figure of *Gammarus locusta*, Fabr. (after Spence Bate and J. O. Westwood).
C = cephalon or head; Th = thorax; Ab = abdomen. (See Table of Appendages, next page.)

called "chitine," with or without the addition of lime,[1] thus forming a defensive covering to the softer tissues of the animal. This hardened envelope serves also as an external skeleton, giving rigidity and support to the internal organs; and to its inflections, projections, and rugosities the muscles and membranes of the body and appendages are attached.

BODY-SEGMENTS.—The crustacean exo-skeleton consists of a series of rings, usually a repetition of each other, and differing only in modification according to the necessity of the various portions of the animal. Each of these divisions is called a *somite* (Huxley).

The normal number of *somites*, or segments, is twenty-one;[2] but instances occur among the extinct Trilobita and the recent Phyllopoda and Branchiopoda, in which a larger number of segments than twenty-one are to be met with. On the other hand, many recent and fossil forms offer examples of Crustacea in which one or more segments are never developed; but this apparent absence is generally due to their coalescence, and we shall not unfrequently find indications of this if we bear in mind the theory of Oken, that each pair of appendages indicates a separate segment. A knowledge, too, of the earlier (larval) stages of some of these forms[3] has revealed the presence of the normal number of free segments in the young individual, which in later life are permanently soldered together.

Although the segments of the Crustacea are greatly modified in the different orders, yet they can nevertheless be shown to be all composed of two lateral moieties resembling each other; we can also distinguish two arcs, the one superior, the other inferior, as shown in the annexed figure (fig. 2).

The superior central pair united constitute the *tergum* (*t*, *t*), and the lateral are called the *epimera* (*ep*, *ep*). The inferior arc is composed of the same number of pieces. The two median pieces unite to form the *sternum* (*s*, *s*), and the latero-inferior pair are called the *episternum* (*es*, *es*). They are always united at the sternum; but there generally exists, between the inferior arc and the epimera situated above, a wide space destined for the articulation of the corresponding appendage (Milne-Edwards).

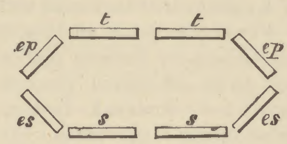


FIG. 2.—Ideal segment.

Mr C. Spence Bate, in his "Report on the British Edriophthalmia" (*Brit. Assoc. Repts.*, 1855), differs from Milne-Edwards and other previous writers who had considered the series of scale-like plates at the sides of the body-segments of the Amphipoda as representing the "epimeral pieces" of each somite; on the contrary, he considers them to be the dilated coxal joint (or *protopodite*) of each limb. This view he adheres to in his chief work[4] (1863, p. 3) on the sessile-eyed Crustacea, and reiterates in his Report[5] (1875, p. 47), where he writes the *epimera* as sectional pieces in a theoretical construction of a somite *cannot exist*; they are really portions of the integument of the appendages. That they are present in the Amphipoda attached to the coxal joint of seven pairs of the limbs is

[1] Chevreul gives the following analysis of the shell of the common crab:—

Animal matter	28·6
Phosphate of lime	6·0
Carbonate of lime	62·8
Phosphate of magnesia	1·0
Soda salts, &c.	1·6
	100·0

[2] In all the higher Crustacea the body is normally composed of twenty-one segments, but, of these, the last never bears true appendages, and is developed subsequently to the others from the dorsal surface of the body. Hence we are justified in regarding it, not as a somite or primitive typical segment of the body, but as a peculiar median appendage, to which the special name of "telson" (Spence Bate) may be applied. Thus the number of somites becomes reduced to twenty, each bearing its pair of appendages (Huxley, *Medical Times and Gazette*, 1857, p. 507). Professor Bell considers the extremely minute and movable points attached to the extremity of this segment in *Palæmon serratus* to be a pair of rudimentary appendages (*Hist. Brit. Stalk-eyed Crustacea*, p. xx., 1853).

[3] As, for instance, the larval stages of *Limulus polyphemus*.

[4] *History of British Sessile-eyed Crustacea*, 2 vols., Spence Bate and J. O. Westwood, 1863.

[5] *British Association Reports*, Bristol, 1875, published 1876.

readily seen; but in the Decapoda, Stomapoda, and Isopoda it cannot by any means be so easily demonstrated. "We know of no example of a ring in which we are able to distinguish all the pieces that we desire to enumerate. In some there is an absence of certain pieces from the places they should occupy; sometimes they are very intimately soldered together, so that we cannot detect even a trace of separation; but in studying each of them separately, where it is most distinct, we shall be able to form a clear idea, and recognize its character in spite of its union with its neighbouring pieces. Moreover, although this analysis of the ring may not be always practicable, it is none the less true that it facilitates much the study of the exterior skeleton of articulated animals, and that it will permit us often to establish analogies where the greatest difference would at first sight appear to exist" (Milne-Edwards).

Professor Huxley in his lectures[1] has somewhat simplified Milne Edwards's view of the crustacean segment. Taking for his type one of the body rings, or *somites*, of the common lobster (fig. 3), he points out that it consists of a convex upper part, called the *tergum* (*t*), and a flatter inferior side, the *sternum* (*s*), the angle of junction on each side of the tergum and sternum being produced downwards, forming what is termed the *pleuron* (or *epimera*) (*pl.*) For ordinary studies this view of a somite will be found sufficiently clear and simple.

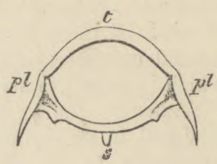


Fig. 3.

From the inner surface of these tegumentary rings in the Crustacea various plates are given off which project into the internal cavity, constituting in some instances cells and canals. According to Milne-Edwards, these processes are always developed at the points of union of two rings or of two neighbouring pieces of the same segment; and this disposition has obtained for them the name of *apodema* (fig. 4). They are the result of a fold of the integumentary membrane which penetrates more or less deeply between the organs, and which is strengthened with calcareous matter like the rest of the external structure, and always formed of two thin plates soldered together. They serve the office fulfilled by the bones in the Vertebrata, *viz.*, that of affording solid surfaces to which the muscles are attached.

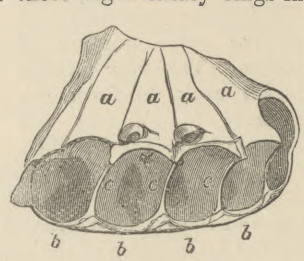


Fig. 4.—Lateral portion of the thorax of a crab (*Portunus marmoreus*). *a, a, a*, the epimera; *b, b, b*, the sternum; *c, c, c*, the apodemata rising from the sternum and separating the insertions of the legs.

Divisions of the Body in the Crustacea.—By general consent and usage the body of a crustacean is divided into three regions, namely, head (or *cephalon*), *thorax*, and *abdomen* (see figs. 1 and 6), to each of which divisions seven out of the twenty-one segments are attributed. These terms are used as a matter of convenience, and are not assumed to be homologous with the grand divisions of *head, thorax*, and *abdomen*, in the Vertebrata.[2] All writers agree in considering the last seven[3] segments to be abdominal. The only difference of opinion is as to the division of the first fourteen,—how many are cephalic and how many thoracic.

Dr Dana is of opinion that Crustacea have no distinct head, but only a *cephalothorax* composed of the fourteen anterior segments, yet he admits that in the Edriophthalmia the seven most anterior pairs of appendages are devoted to the mouth and organs of sensation, and in the extinct *Pterygotus* and in the Trilobita a distinct head certainly exists.

Professor Huxley considers that the division in the Podophthalmia is indicated by the cervical fold and by the sudden change in the character of the appendages between the sixth and seventh somites, and an equally marked similarity between the latter and those of the eighth and ninth pair. So that according to this view we should have six *cephalic*, eight *thoracic*, and six *abdominal* somites (for Professor Huxley regards the *telson* as not being a true somite but a median appendage, like the post-oral plate in *Pterygotus*). But, as Dana well observes, the mouth organs may become legs, or the legs may become mouth organs by slight variations, therefore this line of division can hardly be maintained on the character of the appendages alone, seeing it does not hold good for other groups equally entitled to consideration, as is the Podophthalmia.[4]

The subjoined table may serve to show these several views more clearly:—

Arrangement and Nomenclature of the Somites or Body-rings of the Crustacea, with their Appendages.

1st.	Somite bearing the eyes.	VII. "Segments of *Head*" (Edwards, Bell, &c.)	VI. "*Cephalon*" (C. Spence Bate).	VI. "Cephalic somites" (Huxley).	XIV. "Segments of the Cephalothorax" (Dana).
2	,, bearing antennules, or 1st (internal) antennæ.				
3.	,, bearing antennæ, or 2nd (external) antennæ.				
4.	,, bearing mandibles.				
5.	,, bearing 1st maxillæ.				
6.	,, bearing 2d maxillæ.				
7.	,, bearing 1st maxillipeds.		VIII. "*Pereion*" (C. Spence Bate).	VIII. "Thoracic somites" (Huxley).	
8.	,, bearing 2d ,,	VII. "Segments of *Thorax*" (Edwards, Bell, &c.)			
9.	,, bearing 3d ,,				
10.	,, bearing organs of prehension, ambulatory legs, or natatory appendages.				
11.					
12.					
13.					
14.					
15.	Each somite furnished with a pair of appendages, usually natatory, but variously modified, often branchiferous.	VII. "Segments of *Abdomen*" (Milne-Edwards, Bell, &c).	VI. "*Pleon*" (C. Spence Bate).	VI. "Abdominal somites" (Huxley).	VII. "Segments of the Abdomen" (Dana).
16.					
17.					
18.					
19.					
20.					
(21.)	Caudal somite destitute of appendages, "telson," or median appendage.			"Telson" (C.S. Bate, Huxley).	

The Appendages.—Just as we find a typical number of twenty-one body segments to prevail among the Crustacea, so also in the appendages the type number of joints is seven, any departure from which is disguised by fusion of one or more joints together, the obsolete condition of others, or the depauperization of the limb into numerous *articuli* (see fig. 5). At the coxal joint, or *protopodite*, each limb usually bifurcates; firstly, there arises the external limb proper, or *exopodite*, which is normally seven-jointed; and secondly, the internal branch, or *endopodite*, which may serve as a mouth organ, a branchial appendix, a swimming organ, or a protection for the ova or the young. The appendages

[1] *Medical Times and Gazette*, 1857.

[2] Mr C. Spence Bate, F.R.S., has, since 1855, earnestly advocated the adoption of the terms "*pereion*" and "*pleon*" as less objectionable and more expressive than *thorax* and *abdomen* for the second and third divisions of the body (the term *cephalon* for the head being, of course, generally adopted). In his recent paper "On the Anatomy of the American King-Crab (*Limulus polyphemus*)," *Trans. Linn. Soc.* 1872, vol. xxviii. pp. 462–3, Prof. Owen has proposed the terms "*cephaletron*" and "*thoracetron*" for the anterior and posterior divisions of the body in *Limulus*, and "*pleon*" for the "tail-spine." As other carcinologists are not agreed in regarding the long ensiform tail-spine of *Limulus* as representing the abdomen, we are still left in doubt, and have come to the conclusion that any satisfactory revision of the existing nomenclature must comprehend not one class only but the entire group of the Arthropoda, in the several classes of which the terms proposed to be altered are now in general use.

[3] That is—reckoning the *telson* as the twenty-first segment.

[4] In the Edriophthalmia the normal arrangement mostly is maintained, the fourth to the seventh pairs being epistomial appendages, and the eighth to the fourteenth ambulatory organs.

belonging to the three divisions of the body differ from each other in a greater or less degree in proportion to the higher or lower grade which we examine. Thus among the Decapoda (crabs and lobsters) the cephalic, thoracic, and abdominal somites all possess appendages with well marked

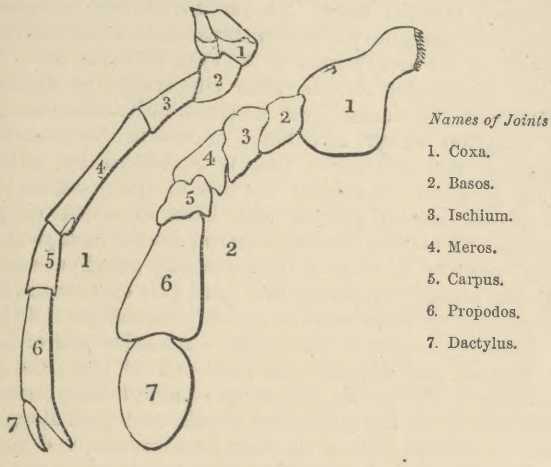


FIG. 5.—(1.) Walking of Lobster (*Homarus vulgaris*), Edw.; (2.) Swimming Jaw-foot of *Pterygotus*.

characters, each series being highly differentiated for the functions to be performed by it. Among the Entomostraca, the appendages of the anterior cephalic somites alone are highly specialized, the others being either mere vegetative repetitions of one another, or else altogether wanting.

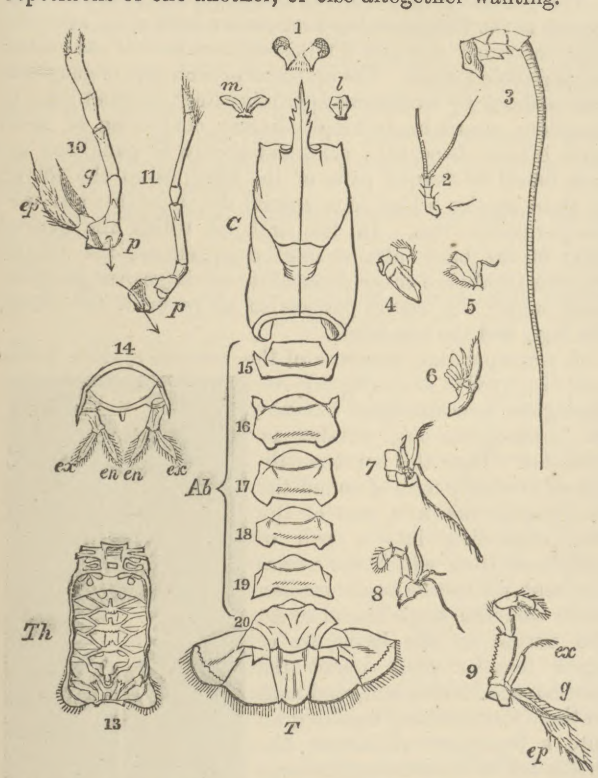


FIG. 6.—Diagram of the segments and appendages of the Common Lobster (*Homarus vulgaris*).

C = cephalon; 13, Th = thorax, showing the apodemata; Ab = abdomen. 1, Eyes; 2, antennules; 3, antennæ; 4, mandibles; 5, first maxillæ; 6, second maxillæ; 7, first maxillipedes; 8, second maxillipedes; 9, third pair maxillipedes. 10, One of the antepenultimate pair of thoracic legs of female; *p*, protopodite; *ep*, epipodite; *g*, gill. 11, One of the last pair of thoracic limbs in male; *p*, protopodite. 14, Third abdominal somite; *ex*, exopodite; *en*, endopodite. *l* = labrum; *m* = metastoma. 15-20, abdominal segments; T, 21st segment, or telson.

First pair.—The first cephalic somite supports the eyes, *the most constant of all the organs,* and probably the only pair of appendages which are never diverted from their normal use, though sometimes atrophied. In the more highly cephalized forms, the Decapoda-Brachyura (crabs), the eyes are placed on the outer side of the two pairs of antennæ, but the anatomical evidence shows that the most anterior pair of nerves, in this as in all other orders of Crustacea, is that which is connected with the ophthalmic organs.

Second pair.—The second somite bears the first pair of antennæ (or *antennules*), called the inner pair in the higher forms, and the upper pair among the lower Crustacea. Ordinarily they are slender, tapering, freely-moving, multi-articulate organs. In the lobster both the endopodite and exopodite are equally developed from a common basal-joint or *protopodite* (see 2 in fig. 6).

Third pair.—The third somite supports the second or posterior pair of *antennæ*, sometimes called the outer pair in the higher, and the inferior pair in the lower forms of Crustacea. In the lobster these are represented by a basal-joint or *protopodite*, and a long filamentary, multi-segmented endopodite, to the outer base of which a small scale is attached representing the exopodite. In all the higher Crustacea the three most anterior somites are always *præoral*, being in front of the buccal orifice, and in most genera, moreover, they are specially set apart as bearing the organs of sense. Generally they are so closely blended together, both in the earlier stages of development and also in the adult forms, as to defy separation, the presence of three somites being only demonstrable by dissection, and by a knowledge of the fact that each pair of appendages, wherever it exists, presupposes a segment or ring to which it belongs. The genus *Squilla* affords, perhaps, the best evidence of the separate existence of these cephalic rings. In it the first, or ophthalmic somite, is quite distinct from the second and third antennary, which are also separable from one another, although the latter blends with the next somite, and the succeeding ones can only be distinguished by dissection. Usually the antennæ or feelers are constant appendages; but still, the number and disposition of these organs varies extremely. Some of the lowest forms are wholly without antennæ, or are furnished with them in a merely rudimentary state. Some species have only a single pair, the normal number, however, as we have already pointed out, is two pairs. In position they are inserted on the superior or inferior surface of the head, according to the development of the somites composing the cephalon. Ordinarily they are slender flexible multi-articulate appendages, but even among the higher forms they are subject to extraordinary modifications; thus in the Scyllaridæ, the external pair are developed into broad flat organs of natation, and probably also for burrowing. In *Arcturus*, an Isopod, they are the nursery for the young; in the Entomostraca they are usually natatory organs; in *Pterygotus* and *Limulus* they are chelate, serving, as in the Copepoda, as clasping organs for the male. In the last free condition of the Cirripedia and Rhizocephala they serve as the organs for attachment,—being converted into cement-ducts in the former, and into root-like organs of nutrition in the latter. The second pair of antennæ and sometimes even the first pair become mouth organs in the Merostomata.

Fourth to Ninth pairs. Epistomial or *Mouth Organs.*—In the Decapoda the six succeeding pairs may be called mouth-organs or epistomial appendages, being all engaged in duties subservient to nutrition. The fourth somite bears the actual jaws or mandibles proper with their palpi, outside which lie two pairs of maxillæ, followed by three pairs of maxillipeds or jaw-feet. In each successive somite, these organs become less highly specialized mouth-organs, and betray the fact that they are after all only simple feet modified. Thus in *Squilla* (a Stomapod) the eighth somite (first thoracic) bears a pair of robust claws, the terminal joint of which is furnished with long and sharp teeth, these forming the principal organs of prehension; whilst the ninth somite bears a pair of ordinary feet like the two following pairs (see fig. 71).

In most of the Edriophthalmia the mouth-organs extend only to the seventh somite, the eighth and ninth being included with the ambulatory members.

In the Decapoda we can detect the more or less rudimentary endopodite and exopodite in the fifth pair of appendages, and in each succeeding pair to the ninth; the eighth and ninth pairs also bear a third organ called an *epipodite*, and a gill or branchial organ.

Tenth to Fourteenth Pairs.—In the higher forms the five somites which follow (and which might be termed the postoral somites) bear the true walking limbs (*pereiopoda*, Spence Bate), the first pair of which in the Decapoda are usually developed into powerful chelæ, and serve as the chief organs of prehension.

These podites are usually seven-jointed, and each bears a gill on its basal-joint. They are formed by the endopodite, the exopodite being present only in the larval-limb of the Decapoda; but in the adult *Mysis* (Stomapoda), eight pairs of limbs (that is to say, the five pairs of *pereiopodites* or "walking-feet," and the three pairs of maxillipeds or "jaw-feet,") are all furnished with two branches, one the *endopodite*, the other the *exopodite*, as in the larval Decapod.

Fifteenth to Twentieth pairs.—The next six somites bear each a pair of swimming-feet (or *pleopodites*). In the Decapoda-Brachyura these remain (like the segments on which they are borne) as extremely rudimentary organs furnished with hairs which serve for the protection of the eggs after extrusion. In the Macroura they assist in swimming, and are composed of a simple exopodite and endopodite. The sixth pair are developed into broad plates, forming the lateral lobes to the tail.

The *Twenty-first* or caudal segment is destitute of appendages, and has therefore been considered by Prof. Huxley and others as a "median appendage," and not as a somite.[1] It varies in form, being sometimes a broad flat plate in the Decapoda, or a minute terminal one in the Amphipoda, or greatly developed as a roof to the branchiæ in some Isopoda, or forming a long terminal spine in the Xiphosura.

INTERNAL STRUCTURE.—NERVOUS SYSTEM.—The typical form of the nervous system in the young of all the Articulata is a chain of ganglions placed along the *ventral* surface of the body, and traversed in front by the gullet. This typical arrangement, however, undergoes great modifications in the several orders of Crustacea. Taking the Edriophthalmia, for example (fig. 7), we find the nervous system to consist of two parallel chords traversing the length of the body, each having its own ganglionic enlargement in each somite in juxtaposition, but not confluent; so that there is a distinct pair of ganglions for each segment. These are again united by transverse commissures, and each ganglionic knot gives off nervous filaments to the limbs of its particular somite.

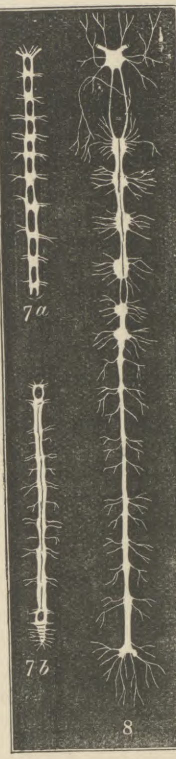


FIG. 7*a*.—Nerves of *Talitrus*.
FIG. 7*b*.—Nerves of *Cymothoa*.
FIG. 8. Nerves of *Homarus*.

In the lobster (Decapoda-Macrura), the nervous system consists of a longitudinally disposed series of different-sized ganglions connected together by commissural cords (fig. 8).

Primitively there is a pair of ganglions to each somite, but the three first pairs are fused together in the adult so as to form a large cerebral ganglion placed in front of the mouth, and called the supra-œsophageal ganglion. From this a nervous chord passes back on each side of the gullet to the large post-oral ganglion, which is made up of six pairs of primitive ganglions fused together. Then follow five pairs of thoracic and six abdominal ganglions all distinct, but connected one with another by a nervous band formed of the primitive commissural chords which have coalesced along the middle line.[2]

No solid internal skeleton separates this nervous axis from the alimentary system, though reflections of the external integument (*apodemata*) pass inwards, and more or less protect it. From this nervous axis all the nerves are given off, but none arise by two distinct roots like the spinal nerves of man.

In the prawn (*Palæmon*) and spiny lobster (*Palinurus*) the thoracic ganglia coalesce to form a long, elliptical, perforated nervous mass. In the hermit-crab (*Pagurus*) the cephalic ganglion presents a transversely quadrate form, sending off the usual nerves to the eyes, antennæ, &c. The lateral œsophageal chords, after supplying the digestive system with the stomato-gastric nerves, unite below to form the ganglion which distributes nerves to the maxillary apparatus and pharynx. This is succeeded by a large oblong ganglion situated at the base of the great nippers, and of the second pair of feet, both of which pairs it supplies. The lateral chords, diverging for the passage of the artery, re-unite to form a third thoracic ganglion, smaller than the second, supplying the third pair of thoracic feet, and sending off three pairs of nerves posteriorly. Of these the lateral pair goes to the fourth diminutive pair of feet; the median pair supplies the fifth pair of feet; the two remaining dorsal nerves, which are of minute size, form the continuations of the abdominal chords, and pass along the under or concave side of the soft, membranous, and highly sensitive abdomen to the anus, anterior to which the last small ganglion is situated; this supplies the nerves to the muscles of the caudal plates, here converted into claspers for enabling the animal to adhere to the columella of the spiral shell which it may have selected to protect the portion of its body undefended by the usual dense and insensible crustaceous covering (Owen).

The general progress of the development of the nervous system in the Crustacea has been, as we have seen, attended with increased size and diminished numbers of its central or ganglionic masses. The divisions of each pair of ganglions first coalesce by transverse approximation; distinct pairs of ganglions approximate longitudinally, conjoining as usual from behind forwards; confluent groups of ganglions are next found in definite parts of the body, as on the thorax of those species which have special developments and uses for particular legs. In the crab, in which the general form of the body attains most compactness, the ventral nervous trunks are concentrated into one large oval ganglion, from which the nerves radiate to all parts of the trunk, the legs, and the short tail.

A corresponding structure of the nervous system is also well displayed in *Maia* (fig. 9.) An analogous concentration, but not an homologous one, obtains in *Limulus*. Here the nervous substance is chiefly massed round the œsophagus, the fore part of the ring expanding into a pair of ganglions, from which the nerves are sent off to the small median ocelli and the large lateral eyes; the nerves to the latter are of great length, wind round the anterior apodemata, and bend back to their termination, breaking up into a fasciculus of minute filaments before penetrating the large compound eye. Two stomato-gastric nerves arise from the upper and fore part of the ring. From the under surface of the fore part of the ring, a small pair of nerves pass to the first short pair of forcipated antennules; five large nerves proceed from each side of the ring to the five succeeding jaw-feet. A pair of slender nerves

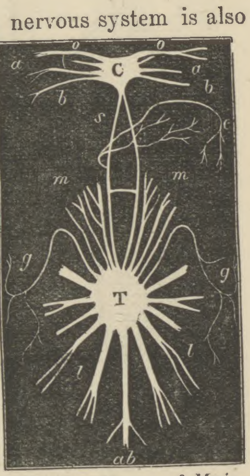


FIG. 9.—Nerves of *Maia squinado*, Latr.
C=cephalic ganglion; T=thoracic ganglion; *o*, *o*, optic nerves; *a*, *a*, antennary nerves; *b*, *b*, *c*, stomato-gastric nerves; *s*, medullary cords uniting C and T; *m*, maxillary nerves; *g*, *g*, nerves of the flanks; *l*, *l*, nerves of the legs; *ab*, abdominal nerves.

[1] Prof. Bell writes:—"Normally there are twenty-one pairs of appendages or limbs; generally speaking, even in the higher forms, *twenty only are perceived*, as the terminal joint of the abdomen, which forms the central piece of the fan-like fin, has none which are perceptible. I have, however, observed them frequently in the common prawn, *Palæmon serratus*, in the form of extremely minute points attached to the very extremity of the segment, and movable." Mr A. H. Garrod, F.R.S., is also of opinion that the telson should be regarded as the twenty-first segment, having its appendages modified by cohesion and adhesion. See Humphrey's *Journal of Anatomy and Physiology*, vol. v. p. 271 (1871).

[2] This double ganglionic chain of the lobster was found by Newport to be composed of two orders of fibres, forming distinct and superposed fasciculi or columns, which the author designates *columns of sensation and of motion*, analogous to the fasciculi of the anterior and posterior columns of the spinal chord of the higher animals. These fasciculi are but indistinctly discernible in the interganglionic chords, but become extremely apparent in the ganglions themselves, for these enlargements belong exclusively to the inferior or *sensitive* fasciculi, and the superior or *motor* fasciculi pass over their dorsal surface without penetrating their substance at all.

pass to the spiny-edged lamelliform appendage. The posterior part of the nervous ring is prolonged backwards in the form of a chord having four ganglionic enlargements on its ventral surface, and terminates opposite the penultimate post-abdominal plate in a fifth slight ganglionic enlargement which bifurcates; each division sends off a few nerves as it proceeds to the caudal appendage, on entering which it is resolved into a plexus or kind of *cauda equina*. Besides the principal nerves above mentioned many smaller nerves are given off to other parts of the body. The sides of the great œsophageal ring are united by two transverse commissural bands; but the most remarkable feature of the nervous axis of this crustacean is its envelopment by an arterial trunk. A pair of aorta from the fore part of the heart arch over each side of the stomach, and seem to terminate by intimately blending with the sides of the œsophageal nervous ring. They, in fact, expand upon, and seem to form its neurilemma; a fine injection thrown into them coats the whole central mass of the nervous system with its red colour (Owen, *Lectures—Invertebrata*, 1855).

Tracing the nervous system in the Crustacea from its simplest type, a vermiform cord with a series of independent nerve centres, we see these becoming successively conjoined in a greater and greater degree, as if in obedience to some law of attraction, until in the crab the maximum centralization of the class is attained. But in whatever form it exists in this section of the Arthropoda we may bear in mind the conclusion that

"the nervous system of the Crustacea consists uniformly of medullary nuclei (ganglions) the normal number of which is the same as that of the members or rings of the body, and that all the modifications encountered, whether at different periods of the incubation, or in different species of the series, depend especially on the approximation, more or less complete, of these nuclei (an approximation which takes place from the sides towards the median line, as well as in the longitudinal direction), and to an arrest of development occurring in a variable number of the nuclei."—(Milne-Edwards.)

Divisions of the Nerves in the Crustacea.—Three principal divisions have been recognized in the nervous system of the Crustacea:—

(1.) All those nervous filaments which take their rise in, and are exclusively connected with, the supracœsophageal nerve-centre, forming the true *sensori-volitional* system. (2.) Other ganglions superadded to the abdominal columns with their nervous filaments, serving for the automatic reception and reflection of stimuli, forming the *motor* system. (3.) The stomato-gastric nerves, connected partly with the brain and partly with the œsophageal columns (analogous to the great sympathetic or organic nerves of the Vertebrata), forming a third group, the *ganglionic* system.

Seat of the Senses in the Crustacea.—Although, as regards the relative size of the several ganglions in the nervous chain of the Crustacea generally, there is little difference between the anterior and posterior masses, and often a disparity between the supra- as compared with the infra-œsophageal ganglions,[1] yet, nevertheless, it is generally admitted that in these animals there is an evident tendency observable towards a centralization of the nervous functions in the anterior portion of the ganglionic chain, viz., the supra-œsophageal ganglion. But still there is a wide interval between this first indication and the concentration of the faculties of perception and of will in a single organ—the brain—of which every other portion of the nervous system then becomes a mere dependency.

Organs of Feeling.—As regards the development of the individual senses, one may reasonably conjecture that the sense of touch can be but feebly exercised by the common integument of the Crustacea, if indeed it can be said to exist at all, except in those parts of the body which remain soft and undefended by a calcareous crust, such as the under side of the abdomen or the soft body of the hermit-crabs. The hairs with which many of the Crustacea are indued may to some extent compensate for this low endowment of the tactile sense.

There can be no doubt, however, that the sense of touch is mainly concentrated in the two pairs of long, many-jointed, and highly flexible antennæ with which numbers of this class are provided. These special organs of touch are directly connected with the cephalic ganglion, and are well adapted, both by actual exploration and as media for conveying vibratory sensations, to furnish to the brain most correct and rapid ideas of surrounding objects.

The smaller but similarly-formed flabelliform appendages attached to the maxillæ and maxillipeds doubtless perform a similar office in the testing of all objects brought near to the mouth; these latter, however, are not directly connected with the supra-œsophageal, but with the mandibular ganglion.

Organs of Sight.—The eyes of Crustacea present a greater variety in their gradation than is to be found in any other class of the Arthropoda.

Commencing with only a median fixed (bifid ?) eye-spot in the larval and simpler forms, we see these organs advance progressively, through all the stages of sessile-eyed development in the Merostomata and Edriophthalmia, to the highest condition in the Podophthalmia, that of two distinct compound eyes, endowed with all the essential optical apparatus, and placed on movable peduncles.

It has been doubted by some naturalists whether the eyes are organs of so much importance in the economy of the Crustacea as are the antennæ or organs of touch; but experiments performed on the eye of the living lobster, when out of water, or even in a shallow aquarium, can hardly be deemed as either a conclusive or a satisfactory test of the sensitiveness of the cornea in an eye accustomed to convey impressions of surrounding objects to the optic nerve when at a depth of several fathoms beneath the water.

If the open-air experiments as to the sensitiveness of the lobster's eye had been made instead on a living shore or land crab, of the genus *Grapsus*, *Gelasimus*, *Gecarcinus*, or *Ocypoda*, it would speedily have been found that in point of rapidity of perception and movement, guided by sight, these shore and land crabs are quite equal to the most sharp-sighted insect, or the most agile of lizards.

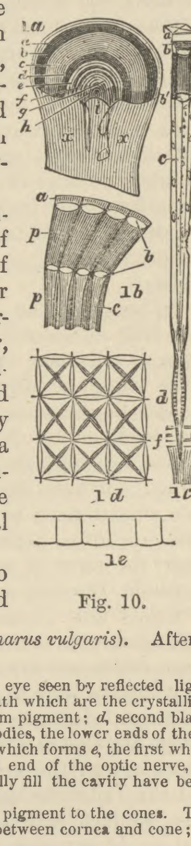


Fig. 10.

Fig. 10.—Structure of Eye of Lobster (*Homarus vulgaris*). After Newton.

1*a*. Longitudinal and horizontal section of a right eye seen by reflected light (× 4). *a*, cornea; *b*, first band of pigment, beneath which are the crystalline cones; *c*, a broad band of radiating fibres free from pigment; *d*, second black band composed of the pigmented spindle-shaped bodies, the lower ends of these bodies are covered with an opaque white pigment which forms *e*, the first white band; *h*, bundles of radiating fibres; *i*, enlarged end of the optic nerve, *x*. The muscles and connective tissue which naturally fill the cavity have been omitted in this figure.
1*b*. A group of elements showing the relation of the pigment to the cones. The cornea is not present. *a*, substance intermediate between cornea and cone; *b*, crystalline cone; *c*, nerve rod; *p*, pigment.
1*c*. A partly diagrammatic view of one of the elements of the eye from the cornea to the optic ganglion. *a*, cornea; *b*, substance between cornea and cone; *b'*, lower end of crystalline cone; *c*, nerve rod, around which is seen the investing membrane with its nuclei; *d*, spindle-shaped or transversely striated body; *f*, perforated membrane at surface of optic ganglion; *p*, pigment.
1*d*. A portion of cornea as seen by reflected light, showing the cross and central spot.
1*e*. Perpendicular section from the middle of the cornea, showing the smooth outer and slightly convex inner surfaces.

As already stated, the eyes are the most constant and persistent organs possessed by the Crustacea as a class;

[1] In *Maia squinado*, for example, although the supra-œsophageal or cephalic ganglion is large, yet, in consequence of the union of the cephalo-thoracic somites, the thoracic ganglion is fully three times its size. See *supra*, fig. 9.

indeed, if we except certain parasitic Isopodous forms and the Cirripedia and Rhizocephala, we shall find that the faculty of sight is possessed by the whole class.[1] Even in those exceptional cases in which the eyes are aborted, we find that in the earlier and larval stages of their existence the parasitic and sedentary forms possessed eyes, and it is only as an effect of a kind of retrograde metamorphosis which the animal undergoes that the organs of vision disappear in the adult.[2] Two forms of visual organs are met with in the Crustacea, namely, smooth or *simple* eyes (*ocelli* or *stemmata*) and *compound* eyes; but though there are some few forms in which (as in *Apus* and *Limulus*) both ocelli and compound eyes are present, the latter form of eyes is that most generally met with in the class.

The structure of the *simple* eye does not differ greatly from that observed among higher animals. There is, firstly, a transparent cornea, smooth and rounded, which is, in fact, only a part of the general tegumentary covering modified. Immediately behind the cornea is the crystalline lens, generally of a spherical form; this is again followed by a gelatinous mass analogous to the vitreous humour, and this mass is, in its turn, in contact with the extremity of the optic nerve. A layer of pigment of a deep colour envelops the whole of these parts, lining the internal wall of the globe of the eye up to the point at which the cornea begins to be formed by the thinning of the tegumentary envelope rendering it transparent. The number of these simple eyes does not exceed two or three.

In the Branchiopoda (*Nebalia*, *Branchipus*, *Daphnia*) behind a simple cornea, undivided externally, we find a variable number of distinct crystalline lenses and vitreous humours, each included in a pigmentary cell, and terminating by contact with the optic nerve. These are, no doubt, an aggregation of stemmata under a common cornea.

In some of the Edriophthalmia a still further advance to a true compound eye is met with. In these the cornea appears to consist of two transparent laminæ, the external layer being smooth and the internal one facetted, each facet being a distinct cornea resting on a separate crystalline lens of its own. In the *compound eye*, properly so called, the two membranes, external and internal, constituting the cornea, are both divided into facets, each facet seemingly being equivalent to a distinct ocellus, furnished with its own crystalline cone (or lens) and nerve rod; each invested with its own pigment coating, which, being darker at intervals, gives to a section through the compound eye as a whole the appearance of pigment-bands repeated at various depths beneath the cornea, and in front of the expanded termination of the optic nerve (*retina*). Although these facets are always hexagonal in the eye of an insect, they are variable in form among the Crustacea. Thus in *Homarus*, *Astacus*, *Penœus*, *Galathea*, and *Scyllarus*, the facets are square; whilst in *Pagurus*, *Squilla*, *Gebia*, *Callianassa*, and the crabs, they are hexagonal. In *Limulus* and the Trilobites the lenses are *round*, not being in actual close contact with each other. Milne-Edwards mentions that in *Idotea* each facet has a kind of supplemental lens of a *circular shape* set within the cornea in front of each proper crystalline lens, and equal in size to the corneal facet, and apparently evolved in the substance of the cornea itself, but under favourable circumstances capable of being detached from it. In *Phacops caudatus* the small circular lenses of the external compound eyes drop out, leaving a corresponding concavity beneath.

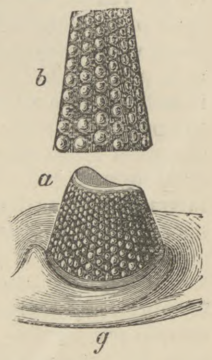


FIG. 11.—Eye of Trilobite (*Phacops caudatus*), U. Silurian. (After Buckland). *a*, the entire eye; *g*, the genal border of head; *b*, a portion of the facetted surface, much enlarged.

Emmerich long since proposed to use the external characters of the eyes of Trilobites as a means of classification, dividing them into "hyaline"-eyed and "facetted"-eyed groups; but he does not seem to have been aware of the perfect analogy which the structure of the eyes of the modern Edriophthalmia afford in illustration of this ancient and extinct group.

Stemmata or *ocelli* are always immovable and sessile; the compound eyes with smooth corneæ, although usually sessile, are, however, occasionally supported on pedicles, as in *Nebalia* and *Branchipus*.

The compound facetted eyes are subject to the same variations,—genera being found with hyaline and facetted corneæ in the same order. In some of the compound sessile eyes the facets are round; but in all the pedunculated compound eyes they are either square or hexagonal.

The peduncles supporting the eyes in the Stomapoda and Decapoda vary greatly in length, but every consideration tends to the conclusion that these movable eye-stalks are really the pair of appendages of the first cephalic ring. Indeed, in *Squilla* one is actually able to separate the eye-stalks with the segment upon which they are borne from the cephalic shield.

In *Macrophthalmus* and some other crabs the eye-stalk is of very considerable length (see fig. 65), extending even to the outer angle of the front of the carapace, which is furnished with a long groove or furrow into which the eye can be folded down, and so placed out of reach of injury when not in active use. This furrow is called the *orbital fossa.*

ORGAN OF HEARING.—Milne-Edwards, Owen, Bell, and others consider the external organ connected with the sense of hearing to be situated on the first joint of the outer and larger antennæ in the lobster and other Macroura, and to consist of a conical process beneath which is a cavity having a round orifice closed by a membrane. Behind the process, and connected with the cavity, is a large sac filled with a clear liquor; a nerve arising in common with the external antennal nerve is spread upon the delicate walls of the supposed acoustic sac.

In *Maia* and other crabs the membrane is replaced by a movable calcareous disc pierced by a small oval opening, over which is stretched a thin elastic membrane (which might be termed the internal auditory membrane), near to which the auditory nerve appears to terminate.

The auditory apparatus of the Crustacea consequently consists essentially of a cavity full of fluid, over which a nerve adapted to perceive sonorous impulses is distributed, assisted by an elastic membrane, and placed near the base of the antennæ which, like a rigid stem, assists in rendering certain vibrations perceptible.

In both the lobster and the crab a gland filled with a greenish substance is connected with the membranous sac. This structure and the absence of otolites has led Farre to suggest that the organ may be olfactory; but the chief

[1] The fact that *Niphargus*, *Crangonyx*, and some other dwellers in subterranean waters, as well as *Callianassa Macandrei*, a burrowing marine crustacean, are blind, is certainly the result of their habitats, not a normal state of the organs of vision. In the Mammoth Cave, Kentucky, and the caves of Carniola and Adelsberg, Crustacea, insects, and other animals have been met with, all blind or with but imperfect organs of vision.

[2] In the Cirripedia the individuals are *hermaphrodite*, fixed when adult, and all blind (unless the complemental male of *Ibla Cumingii* be an exception,—see Darwin's *Mon. Cirripedia*, Ray Soc., p. 196), but in the parasitic Isopoda, and in many of the Copepoda, it is the female alone which is so remarkably transformed, whilst the male retains his powers of sight, his freedom, and his normal aspect.

parts of the structure bear a close correspondence with an auditive vesicle and a tympanic membrane.[1]

ORGAN OF SMELL.—Professor Owen[2] refers the sense of smell to a small sac, fringed with fine hairs, opening externally by a narrow cleft in the basal joint of the first or median antennæ. A branch of the antennal nerve terminates in a small prominence at the bottom of this sac. From the presence of some minute siliceous particles within the cavity (although it is admitted that these must have found their way in from the exterior fortuitously) Dr Farre[3] has been led to suggest that the small antennæ are acoustic organs, and that the grains of sand may act as otolites.

Milne-Edwards admits as indubitable the presence of well-developed organs of smell, but considers we are reduced to conjecture when we are required to point out the precise seat of those organs.[4]

ORGANS OF TASTE.—Like almost all other animals the Crustacea *select* their food, showing decided preference for particular kinds; this selection is doubtless actuated by two senses, *smell* and *taste.* Whether we are correct in assigning to the inner pair of antennæ the duties of the olfactory organ or not, it cannot be doubted that the sense of taste is distributed over that portion of the tegumentary membrane which lines the interior of the mouth and œsophagus, but there is no modification of these parts which needs to be specially noticed here.

ORGANS OF NUTRITION.—In the larval stages of the higher Crustacea, and also among the adult lower and simpler forms, fewer of the somites have their paired appendages differentiated to perform special offices. Thus in the larval Decapod the chief natatory organs are the maxillipeds; this is also the case in the Merostomata. In *Limulus* (fig. 12) all the locomotory organs are also subservient to the

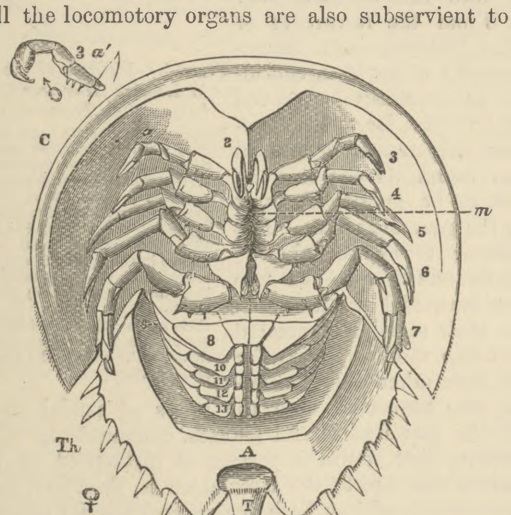


FIG. 12.—Underside of *Limulus polyphemus*, Latr. ♀
C=cephalon; Th=thorax; A, rudimentary abdomen; T=telson. (The eyes 1, cannot be seen in this figure, being on the upper surface of head-shield.) 2, The chelate antennules; 3*a*, antennæ (3*a′* detached antenna of male); 4–7, mandibles, maxillæ, and maxilliped; *m*, the mouth; 8, operculum, bearing on its inner and upper surface the ovaries and reproductive organs; 9–13, branchigerous feet.

duties of nutrition, being organs of locomotion at their distal, and mandibles and maxillæ at their proximal extremity.

In fact, as already stated, we have abundant evidence to prove that the maxillary organs of the Malacostraca are but modifications of entire limbs, translated from the locomotive series and set apart as special mouth-organs. By far the larger proportion of the Crustacea have a proper normal mouth furnished with suitable organs of mastication, but among the parasitic Copepoda and certain aberrant parasitic Isopods, &c., they become merely organs of attachment, the mouth being suctorial; or (as in the Rhizocephala) it may be altogether wanting, and the limbs completely lost, and from the point of attachment root-like tubes may be developed, which, sinking deep into the body of the host, convey to the parasite its nutriment ready digested and prepared.

If instead of these latter we examine the Decapoda we shall find the mouth placed centrally near the front and upon the under side of the cephalon. It is provided with a small simple median piece, called a *labrum*, or upper lip, in front, and a bifid *metastoma*, or lower lip, behind; the paired appendages (mandibles, maxillæ, &c.) being placed on either side of the buccal orifice.

The food, whether living or dead, being first seized by the forcipated thoracic feet, is brought near to the maxillipeds, and by the help of these external organs of prehension portions are separated and introduced by the maxillæ to the trenchant and powerful mandibles, when having undergone further subdivision they are swallowed.

No organ corresponding to a tongue exists in the Crustacea, the mouth being only the anterior and outward expansion of the œsophagus, which is short, rises vertically, and terminates directly in the stomach.

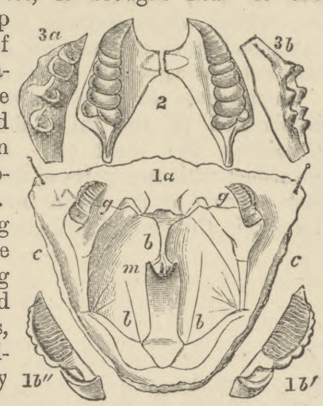


FIG. 13.—Gastric Teeth of Crab and Lobster.
1*a*, Stomach of common crab, *Cancer pagurus*, laid open, showing *b*, *b*, *b*, some of the calcareous plates inserted in its muscular coat; *g*, *g*, the gastric teeth, which when in use are brought in contact with the sides of the smooth fixed plate *m*; *c*, *c*, the muscular coat; 1*b′* and 1*b″*, the gastric teeth enlarged to show their grinding surfaces; 2, gastric teeth of common lobster, *Homarus vulgaris;* 3*a* and 3*b*, two crustacean teeth (of *Dithyrocaris*) from the Carboniferous series of Renfrewshire.

The wall of the stomach is composed of two membranous layers, separated by one of muscular fibres, which increase in thickness at the openings leading from the œsophagus and into the intestine.

The stomach is globular in form and of great capacity, and may be divided into an anterior or "cardiac" part, and a posterior or "pyloric" region. The food on reaching the "cardiac" region of the stomach is subjected to a further process of mastication, by means of a complex apparatus composed of several calcareous pieces, moved by appropriate muscles, inserted in the membranous wall of the stomach (fig. 13, 1*a*), armed with a smooth median plate and two lateral molar-like-organs, having a singular *mimetic* and superficial resemblance to the molar teeth of some small marsupial rodent. Two smaller points (bicuspid in the lobster, tricuspid in the crab) complete the calcareous apparatus; in the pylorus a series of fine hairs are placed, which, doubtless, act like a strainer, preventing the escape of the coarser particles of the food until they have repeatedly been subjected to the molar-like action of the gastric teeth. A long and straight intestine continues from the stomach backwards, and terminates beneath the telson.

Two cœcal salivary glands of a greenish colour are situated on either side of the œsophagus.

The liver in the Decapoda is of large size, and bilaterally symmetrical: its structure is highly ramified, not solid like the human liver. The secreted fluid or bile is poured by two openings into the pylorus.

[1] Spence Bate marks this organ as "olfactory" in the crab (*Brit. Assoc. Reports*, Bristol, 1875, pl. i. fig. 10, and explanation). Mivart calls the green gland the kidney of the lobster, and says "no organ of smell has been determined" (*Pop. Sci. Rev.*, vol. vii., 1868, p. 350) See Fritz Müller's suggestions as to this green gland, p. 652.

[2] *Lectures Comp. Anat.* 1855, 2nd edition, p. 311.

[3] *Phil. Trans.*, 1843.

[4] Milne-Edwards, in Todd's *Cyclopædia of Anatomy*, vol. i. p. 758.

This organ, so large in the crab, undergoes great modifications in the various orders; in the Edriophthalmia only three pairs of biliary vessels, analogous to those of insects, remain. No vessels have as yet been detected by which the chyle or nutritious fluid elaborated by the digestive processes is taken up, as it passes along the intestinal canal, and transferred to the circulatory system; we can only, therefore, conclude that it is transferred by absorption to the irregular venous receptacles which are in contact with the walls of the intestines.

Circulatory System.—In most of the Crustacea the circulation is of the same simple character as that observed in the aquatic larvæ of insects, save that in the Crustacea the blood is conveyed to the gills for the purpose of oxygenation; but where no special respiratory organs are developed, the fine hairs and filamentous appendages attached to the feet doubtless subserve that office, or in some the entire surface of the body. The heart consists of an elongated contractile dorsal vessel, larger behind than before, connected anteriorly and posteriorly by several branches with the inferior or returning vessels, which running along the whole body receive the blood from the anterior extremity, and carry it into the posterior extremity of the dorsal vessel.

In the male *Entoniscus Cancrorum* the heart (fig. 14). is situated in the third abdominal segment. In the *Cassidina* the heart (fig. 15) is likewise short and furnished with two pairs of fissures, and is situated in the last segment of the thorax and the first of the abdomen. Lastly, in the young *Anilocra* the heart (fig. 16) extends

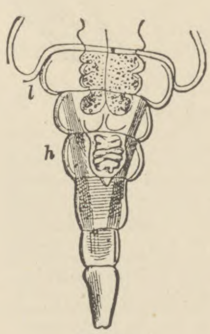


Fig. 14.

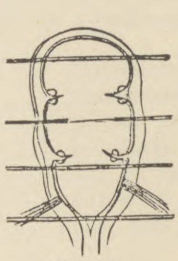


Fig. 15.

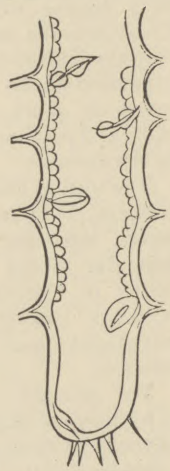


Fig. 16.

Fig. 14.—Abdomen of the male of *Entoniscus cancrorum*. *h*, heart; *l*, liver. (Fritz Müller).[1]
Fig. 15.—Heart of a young *Cassidina*. (Fritz Müller.)
Fig. 16.—Heart of a young male *Anilocra*. (Fritz Müller.)

through the whole length of the abdomen, and is furnished with four or five fissures which are not placed in pairs, but alternately to the right and left in successive segments (Fritz Müller, *Für Darwin*, pp. 41-42).

In the Decapoda the heart is placed near the dorsal surface of the cephalic shield immediately beneath the integument above the intestinal tube, and is retained in its place by lateral pyramidal muscles. It consists of a single chamber or ventricle, suspended in a large sac, called the *pericardium*, but wholly distinct from the part so named in man. The structure of the heart is made up of the interlacement of numerous muscualr fibres fixed by their extremities to neighbouring parts, and passing for some distance over the aggregate at each end, the whole structure reminding one of a number of stars superposed on each other, the rays of which do not correspond (Milne-Edwards). The ventricle has three pairs of apertures so closed by valves as to readily allow the entrance of blood from the pericardium, but to hinder its regurgitation. It has three other pairs of openings, each of which is the commencement of an arterial trunk conveying blood all over the body. These arteries have valves at their origin, and ramify and end ultimately in capillaries, which open into what are called venous sinuses, because they are channels without any definite shape. The venous blood collects in a great sternal sinus, and thence passes up into the gills to be oxygenated, after which it proceeds to the pericardium to find its way into the ventricle (fig. 17). From the researches of MM. Audouin and Milne-Edwards,[2] it had been considered as conclusively proved that in the Decapod Crustacean only aerated or arterial blood found its way into the heart, to be distributed by it over the general system. But Professor Owen has shown[3] that in addition to the two great branchial trunks which pour their streams of aerated blood into the heart from the gills, four other valvular orifices, two connected with the series of caudal, and two with the series of lateral sinuses, communicate with the ventricle, and return a portion of carbonized or venous blood to the heart; the circulation is, therefore, to some extent mixed, and as both venous and arterial blood reach the ventricle, they are propelled thence through the system (see fig. 18). The returning blood is not redistributed through the liver, as in man, *i.e.*, there is no portal circulation. There are no lymphatic vessels. The blood is a slightly dusky fluid, containing numerous nucleated corpuscles, which change their form with remarkable rapidity.

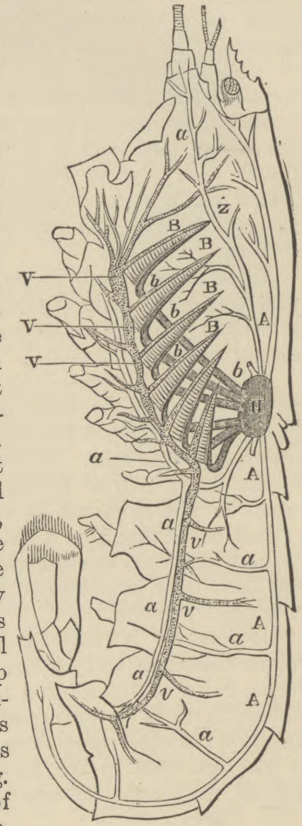


Fig. 17.—Diagram of Circulation of Lobster (*Homarus vulgaris*). (After Allen Thomson.)
H=heart. The aortic heart consisting of a single ventricular cavity, and situated below the posterior margin of the thoracic shield, gives off six systemic arteries (A, *a*), which convey the arterial blood to the various organs of the body and to the liver (*l*). The venous blood returning thence in the systemic veins (*v*, *v*) is collected on the lower surface of the body into sinuses (V, V), from which the branchial arteries (B, B) take their origin; the branchial veins (*b*) return the blood which has passed through the gills to the heart. See also fig. 18.

Respiratory Organs.—As the type upon which the Crustacean class is constructed is specially fitted for aquatic existence, branchial organs or gills in some form are essential for the aeration of the blood. The appendages which fulfil this office are attached either to the thoracic or abdominal members or to both. Where they are most highly developed, as in the crab and lobster, they assume

[1] By the kindness of his friend, Mr Charles Darwin, M.A., F.R.S., &c., &c., the present writer has been permitted to use a large number of the illustrations from the English edition of Fritz Müller's admirable little book, entitled *Facts and Arguments for Darwin*, translated from the German by W. S. Dallas, F.L.S., Assistant Secretary Geol. Soc. Lond. From Fritz Müller's store of interesting facts and observations the writer has also largely drawn, especially in regard to his researches in the larval development of the Crustacea, and he takes occasion at once to acknowledge the same with thanks.

[2] Recherches Anatomiques et Physiologiques sur la Circulation dans les Crustacés, *Ann. des Sciences Nat.*, t. ii.

[3] *Lectures on Comp. Anatomy and Physiology of the Invertebrata*, 2d edition, 1855, p. 318.

the form of pyramidal bodies, each consisting of a central ascending stem, with numerous horizontal branches or plates folded close together through which the blood circulates. There are twenty-two such structures in the lobster, eleven on each side of the thorax, attached to the basal joints of the thoracic limbs,[1] each pair of gills being furnished with its epipodite, or upper footlet, which serves to keep the gills apart from each other. In their most simple form they consist of a mere sac-like appendage held by a small neck pendant from the coxal joint, and exposed in the water without protection.

In the Decapoda they become more complex in structure and more voluminous, and would be extremely liable to injury if not protected by some means. But, as Spence Bate[2] truly observes, being *external* to it, they could not be covered or protected by their own somite, as, if it had passed over them, the branchial appendages would have become internal, their character and constitution would therefore be changed; they would cease to be external; in fact, they would cease to be branchiæ. These appendages, however, exist as branchiæ, and are nevertheless securely covered and protected; not, indeed, by their own somite, but by the great development of the mandibular and posterior antennal somites incorporated together, forming the carapace so characteristic of the typical Crustacean.

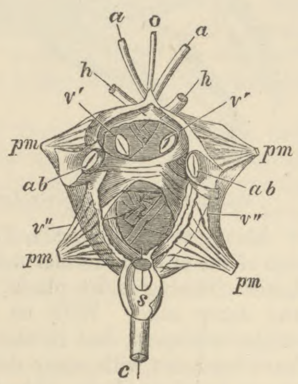


Fig. 18.—Heart of *Homarus vulgaris*, Edw., laid open. (Copied from Owen's Lectures, p. 318.)

o, the ophthalmic artery; *a*, *a*, the antennal arteries; *h*, *h*, the hepatic arteries; *v'*, *v'*, openings to dorsal sinuses protected by semilunar valves; *ab*, *ab*, large orifices by which the arterial blood from the branchiæ enters the heart; *v''*, *v''*, orifices by which lateral sinuses conduct venous blood to the heart; *s*, sternal artery; *c*, superior caudal artery; *pm*, *pm*, lateral pyramidal muscles which retain the heart *in situ*.

N.B.—Bristles have been passed through the orifices *v''*, *v''*, to indicate their position.

The branchial appendages are thus external in relation of the body of the animal, but covered over and protected by the lateral walls of the carapace. To complete this so as effectually to protect these organs without pressing on them or interfering with their functions, a very considerable amount of lateral development has taken place, and a peculiar reflection so as to bring the margin of the carapace below the branchial appendages, and to protect them from rude contact with the limbs. Externally, the carapace covers and protects both the hepatic and branchial organs; but, internally, a calcareous wall of demarcation exists between the two. This wall, which Milne-Edwards terms the *apodema*, is continued into a thin membranous tissue that makes a distinct and well-defined separation between the branchial appendages and the internal system, so that the aqueous element so necessary for the aeration of the blood as it passes through the branchiæ may have full power to play upon the gills, and yet leaving no passage that would admit it to the internal viscera so as to derange the general economy of the animal (Spence Bate). The gills are not ciliated, and thus they require that the water within the branchial cavity in which they are placed should be incessantly renewed by other means. In the crabs two passages communicate with the branchial chamber, one for the entrance, the other for the exit of the water necessary to respiration. The efferent orifice always opens on each side in front of the mouth under the posterior maxilliped. The afferent opening varies greatly in position in the different groups.

In the Macroura (lobsters), and in some of the Anomoura (hermit-crabs), the margin of the carapace is not accurately fitted to the thorax along its lower lateral border; the branchial cavity is thus open along the whole extent of its inferior edge, and so the water finds its way readily into the respiratory chamber.

In the Brachyura (crabs), the afferent orifice is more circumscribed, but varies in a still greater degree. In nearly all it exists as a cleft of considerable breadth in front of the base of the first pair of ambulatory appendages between the carapace and the thorax.

In the Ocypoda, the third and fourth pair of feet are more closely approximated than the rest, and their margins bear a dense border of long silky peculiarly-formed hairs. Between the basal-joints of these feet, Fritz Müller has discovered a round orifice opening into the branchial cavity, and he finds this to be a true incurrent orifice for the admission of air or water into the branchial chamber.[3]

In the genus *Ranina*, according to Milne-Edwards, the ordinary anterior entrant orifice to the gill-cavity is altogether wanting; it is placed instead at the origin of the abdomen.

In *Grapsus*, Fritz Müller[4] has observed that, when under water, the respiratory in-current enters near the front in the usual manner, but when air is breathed, the anterior incurrent orifice being closed, and the hinder border of the carapace elevated, a wide fissure is opened upon each side above the last pair of feet leading directly into the branchial chamber.

In *Leucosia* the two apertures are close together, the incurrent opening being situated in front of the mouth, and the water passing in by a conduit parallel to the excurrent canal. The circulation of the medium within the respiratory atrium is brought about partly by the movements of the legs to which the branchiæ are attached, and partly by the epipodites which ascend between the gills. The main agent, however, is the "scaphognathite," a flabelliform appendage of the second pair of maxillipeds, which, rising and falling continually, occasions a rapid current from behind forwards in the water, filling the branchial chamber.

Branchiæ such as we have described, enclosed beneath the overarching lateral walls of the carapace, are specially characteristic of the Decapoda (crabs and lobsters).

In the Amphipoda the head shield is small, and no longer covers the thoracic somites, as in the Decapoda. The branchiæ, however, are still borne on the coxal joint of the thoracic legs, but they depend unprotected from each limb, and are bathed in the surrounding medium, which is made to pass rapidly over them by the action of the abdominal flabellæ.

In *Squilla* we find the appendages of the first five pairs of abdominal somites devoted to the office of aerating the blood; the branchiæ, however, are not included in a cavity, but float freely in the water which bathes the entire surface of the animal.

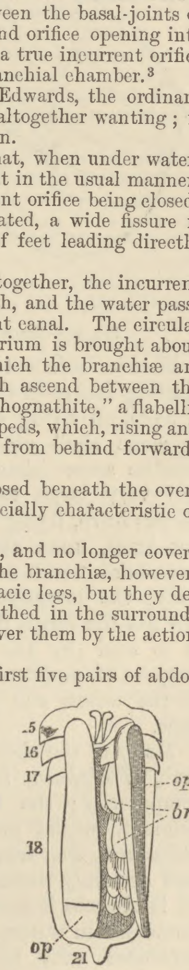


Fig. 19.—Branchiæ of *Idotea*.

op, operculum; *br*, branchia. The numbers indicate the segments.

In the Isopoda the abdominal appendages are all devoted to respiration, the anterior and outer pair in *Idotea* (fig. 19) being specially modified into a strong *operculum* (*op*), opening laterally and shutting over the five pairs of delicate branchial appendages within.

In *Limulus* five pairs of thoracic feet are modified into broad lamellæ, to the inner and upper surfaces of which the gills are attached, whilst the most robust and anterior pair is modified into a broad operculum covering the succeeding five branchigerous pairs, and also the reproductive organs (see fig. 12).

In *Apus* (Branchiopoda), save the antennæ and oral appendages of the head, all the other somites bear simple lamelliform gill-feet, of which there are, according to Baird, about sixty pairs, affording an excellent illustration of mere vegetative repetition of parts.

Although the act of respiration by gills seems a peculiarly aquatic method of aerating the blood, yet in both the

[1] "The number of branchial pyramids," says Milne-Edwards, "varies greatly, especially in the Macroura; at the most it is twenty-two, as in *Astacus*, and nearly allied species; in other Macroura the number is eighteen, as in *Palinurus*, *Scyllarus*, *Penæus*; fifteen in *Gebia*; twelve in *Pandalus*; ten in *Callianassa*; eight in *Palæmon*; seven only in *Crangon*, *Hippolyte*, *Sergestes*. In the Anomoura the number also varies very much. In the Brachyura we can almost always reckon nine branchiæ on each side; two of this number are, however, merely rudimentary. Sometimes one or more of the last, or last but one, are entirely wanting" (Todd's *Encyclop.* vol. i. p. 781).

[2] Report on the present state of our knowledge of the Crustacea, part i., *British Assoc. Reports*, Bristol, 1875, p. 49.

[3] *Facts and Arguments for Darwin*, by Fritz Müller. Translated by W. S. Dallas (Murray), 1869, p. 34.

[4] *Op. cit.*, p. 31.

Podophthalmia and the Edriophthalmia we meet with numerous amphibian and terrestrial forms.

No Macrouran Decapod, so far as ascertained, voluntarily quits the water, although the common lobster, the river crayfish, and the spiny lobster, all display great tenacity of life when removed from their native element. Their inability to leave the water is, no doubt, due to the fact that the carapace is less acurately fitted to the thorax than in the crabs. Certain of the Anomoura, or hermit-crabs, however, find no difficulty in adapting themselves to terrestrial conditions. The writer has kept the *Cenobita Diogenes* from the Antilles, tenanting an *Achatina* shell, alive in a Wardian case for three months, during which period he displayed great activity and most remarkable powers as a climber. These West Indian crabs are not infrequently brought over alive to England with cargoes of guano and other natural products (fig. 20).

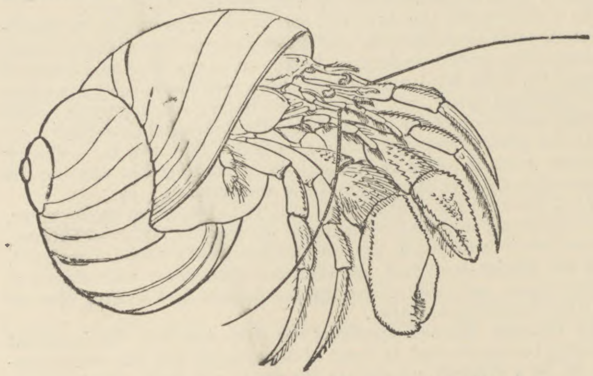


Fig. 20.—Hermit-Crab (*Cenobita*) in shell. (After Morse.)

Darwin refers to the abundance of hermit-crabs on Keeling Island in the Indian Ocean (*Voyage of the Beagle*, p. 544), all living on the cocoa-nut, and each ensconced in some shell obtained from the neighbouring beach. On the same island is found another most remarkable and very large terrestrial Anomourous Crustacean, the *Birgus latro*, living in burrows at the base of the cocoa-nut trees, upon the fruit of which it subsists. This large hermit-crab seeks no artificial covering for its fleshy body, the integument of which is chiefly membranous, but has the tergal pieces of its abdominal somites calcified. It is said (by Darwin) to visit the sea nightly for the purpose of moistening its gills, and the young are hatched in the water, and pass there their earlier stages of existence.

Many of the shore-crabs, as *Grapsus*, and the freshwater crab, *Thelphusa*, are not only able to leave the water temporarily; the former *habitually* lives out of that element, whilst many sub-tropical forms, as *Gecarcinus*, *Gelasimus*, &c., frequently live at a distance from the sea, and certainly possess the power of breathing air. But in all land-crabs it seems essential that the gills should, if not immersed in water, at least have the air surrounding them *saturated with moisture*. Milne-Edwards found that *Gecarcinus* (fig. 21) has the membrane lining the walls of the respiratory cavity modified in a manner analogous to that observed in fishes of the order Acanthopterygiæ. Sometimes this provision consisted of folds and *lacunæ* serving as reservoirs for the water; sometimes, as in *Birgus*, of a spongy mass well calculated to store up the fluid necessary to keep the branchiæ sufficiently moistened to enable them to perform their functions.

The swift-footed sand-crabs (Ocypoda) are exclusively terrestrial, and can scarcely live for a single day in water; in a much shorter period, a state of complete relaxation occurs, and all voluntary movements cease. In fact, these land-dwelling crabs are as truly asphyxiated by immersion in water, as the aquatic species of *Cancer* become when taken from that element and left in the air.

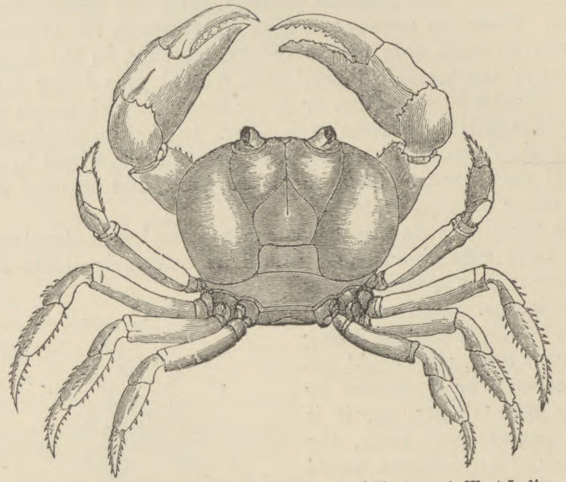


Fig. 21.—*Gecarcinus ruricola*, Land-crab of Montserrat, West Indies.

Among the Amphipoda, *Talitrus* and *Orchestia* both live out of the sea, the former making a burrow for itself, the latter choosing moist places under sea-weed, or hiding in the damp sand. With us *Orchestia* lives within reach of the sea spray, but in the southern hemisphere species have been met with many miles inland, choosing terrestrial plants for their abode, sometimes at an elevation of 1500 feet above the sea.

Among the Isopods *Sphæroma* is quite a littoral form, ranging from the equator to the colder temperate shores. The genus *Ligia* also lives above high-water mark, but never far away from the sea.

All the Oniscidæ are terrestrial in their habits, living under stones, moss, or decaying wood, and in similar damp situations; they breathe air (which, however, must be saturated with moisture) by the aid of a series of respiratory branchial plates on the under side of the abdominal somites, in the same manner as in *Idotea* (already noticed), and in addition to this by the inspiration of air by means of certain spiracular orifices on several of the basal pairs of these same appendages (fig. 22).

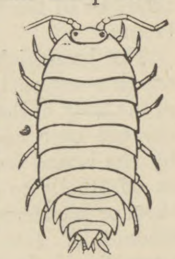


Fig. 22.—Common Woodlouse, *Oniscus asellus.*

In a large number of the lower and simple forms, including also the parasitic Crustacea and the Cirripedia, no special organs of respiration exist, and we are led to conclude that this office is performed by the surface of the body and its appendages generally.

Muscular System.—All the muscles of the body, even those of the intestine, are composed of striated fibres.

Reproductive Organs.—The organs of generation are easily to be discerned in most of the Crustacea, but the analogy between these parts in the male and female is so great in many genera as to need the most careful examination in order to discriminate between the two. Generally, however, the males may be discerned by their having one or more pairs of limbs especially modified to assist in the marital act.

With the exception of the Cirripedia the two sexes appear never to exist together in the same individual among the Crustacea.

The small size and great dissimilarity of the males of some of the parasitic genera caused them to remain long unknown, and led to the error of supposing the females to be hermaphrodite, as Darwin has shown to be really the case in the Cirripedes. But even in this division

Darwin has found small males parasitic on the female which he has named "complemental males." They are destitute of a mouth, and appear to exist only for the performance of this one function of reproduction (Darwin, *Cirripedia*, Ray Soc. 1851).

Bilateral symmetry generally prevails among the members of this class, and as a consequence we find always a pair of these organs arranged one on either side of the body, perfectly distinct, and often wholly independent of each other. The male is provided with a paired gland or testes, and two excretory ducts, by which the spermatozoa are discharged on reaching the efferent openings, usually situated on either side in the basal joints of the seventh pair of thoracic appendages, or the first pair of abdominal limbs. In both the Crab and Lobster the first pair of abdominal appendages of the male are specially modified to take part in the process of fecundating the female.

Milne-Edwards denies that these appendages have any claim to be considered as fulfilling the office of conveying the fecundating fluid to the body of the female, but Spence Bate has frequently taken *Carcinus mœnas* with these styliform appendages deeply inserted within the vulvæ of the female. He has also shown the existence of a *vas deferens* in these false feet (*Ann. and Mag. Nat. Hist.*, 2nd series, vol vi., p. 109).

The ovaries in the crab resemble four cylindrical tubes placed longitudinally in the thorax, and divided into two

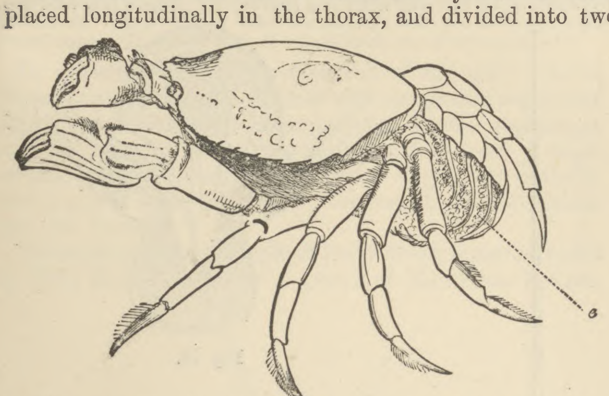


FIG. 23.—Side view of Crab (Morse), the abdomen extended and carrying a mass of eggs beneath it; *e*, eggs.

symmetrical pairs, each opening into a distinct oviduct, yet communicating with each other by a transverse canal and by the intimate union of the two posterior tubes. The oviducts and ovaries are of a whitish colour, and become united to a kind of sac[1] on each side, the neck of which opens externally in the sternal pieces of the fifth thoracic somite, which bears the third pair of walking appendages.

In the Anomoura and Macroura there are no copulatory pouches, and the vulvæ open on the basal joint of the third pair of ambulatory legs. It is possible, therefore, that in these forms the fecundation of the ova does not take place until the eggs are actually extruded, which we know to be the case in *Limulus*, and probably in some other forms, and as is also the case in fishes.

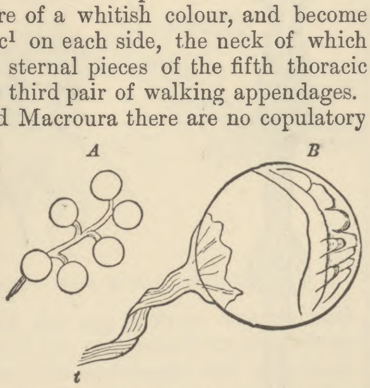


FIG. 24.—A, a few eggs of the Common Crab enlarged; B, a single egg greatly enlarged, showing more plainly the hardened thread (*t*) by which they are attached to each other. This egg also shows the commencement of the development of the embryo. (Morse's *Zoology*.)

If we except *Gecarcinus*, certain other land-crabs, and *Limulus*, the female does not abandon her eggs after their extrusion. Those of the Decapoda when extruded are coated with a viscous secretion which thickens into threads, and causes the eggs to adhere to each other and to the fine hairs with which the swimmerets of the abdomen of the lobster and the female crab are fringed (fig. 23). Fig. 24 shows the method of attachment of the eggs. Here they are retained securely until the period of hatching has arrived, when the brood in most cases is dispersed.

This is not, however, always the case, for whilst examining a female *Dromia* from Australia, the writer discovered more than a dozen young ones adhering to the false abdominal feet of the parent,—the young, except in size, agreeing perfectly with the parent.

In *Mysis* the two endopodites of the hinder pair of thoracic feet in the female are developed into a broad plate on either side, and bent under the sternum, thus forming together an incubatory pouch or marsupium, in which the eggs are first deposited, and within which the young are secluded during their minority. In Thysanopoda the eggs and young are contained in a pair of oval sacs dependent from the posterior feet, forcibly reminding one of the ovarian sacs in *Cyclops*.

In the Amphipoda the ova are nurtured by the female within a pouch formed by a series of foliaceous plates, one of which is attached to each of the four anterior pairs of legs of the thorax. In the genus *Podocerus* the parent builds a nest in a very bird-like manner, amid the branches of the submarine zoophyte forests, and in one of these Mr Spence Bate met with two broods of different ages, clearly demonstrating that the maternal care for their young is continued long after birth.[2] Similar ovigerous plates are developed in the fore-legs of females of the Isopoda. In all these sessile-eyed forms the parent seems specially solicitous for the safety of its young. In *Asellus, Talitrus,* and *Gammarus*, they appear to quit the maternal pouch and return to it as to a place of safety. *Caprella* carries its young attached to its body; the female *Arcturus* supports them adhering to her large antennæ.

In *Daphnia*, besides the several groups of ova which are successively hatched within the bivalved shell, and excluded during the spring and summer, giving rise to fertile females, there is formed each autumn an opaque layer within the incubatory cavity of the female, which hardens in two pieces like a small bivalved-shell, and is called the *ephippium* or saddle, and is placed on the dorsal surface of the *Daphnia*, but within the shell of the parent. Another structure, similar to the *ephippium*, and called the "internal ephippium," placed within it, is found to contain two bivalved capsules, in each of which a fertilised egg is lodged, which remains in a passive state through the winter, but hatches by the first warmth of spring, giving rise to females only (no males being hatched till autumn), these females in turn giving rise also to as many as six generations of fertile females. Their fecundity is so great as to be almost beyond the power of figures to express.[3]

DEVELOPMENT OF THE CRUSTACEA.—In nearly all the Crustacea, the young undergo a series of metamorphoses *after quitting the egg*. This rule appears to apply more constantly among the truly marine forms. Among the stalk-eyed Crustacea some few species at least quit the egg in the form of their parents, with the full number of jointed appendages to the body. This is the case, according to Rathke,[4] with *Astacus fluviatilis*, the common river crayfish (fig. 25), and according to Westwood[5] in a West Indian land crab (*Gecarcinus*). The present writer has

[1] The *copulatory pouches* of Milne-Edwards.

[2] Spence Bate, 1858, *Annals and Mag. Nat. Hist.*, and Bate and Westwood, *Sessile-eyed Crustacea*, vol. i. pp. 443–4.

[3] Baird, *British Entomostraca*, p. 78.

[4] Rathke, *Untersuchungen über die Bildung und Entwickelung des Flusskrebses*, fol. 1820.

[5] J. O. Westwood in *Phil. Trans.* 1835, vol. cxxv. p. 311. Fritz Müller remarks, in reference to Westwood's paper—This is a solitary exception of a single species investigated by Westwood. In the same genus Vaughan Thomson found zoëa-brood, which has also been met with in other terrestrial crabs (*Ocypoda* and *Gelasimus*). The mode of life is in favour of Thomson. "Once a year," says Troschel, "they migrate in great crowds to the sea in order to deposit their eggs, and afterwards return, much exhausted, towards their dwelling-places, which are reached only by a few." For what purpose would be these destructive migrations in species whose young quit the egg and the mother as terrestrial animals? Fritz Müller, *Facts and Arguments for Darwin*, translated by W. S. Dallas, F.L.S., 1869, p. 43.

also found an Australian *Dromia* protecting its brood on its false abdominal feet, the young differing from the parent only in point of size.

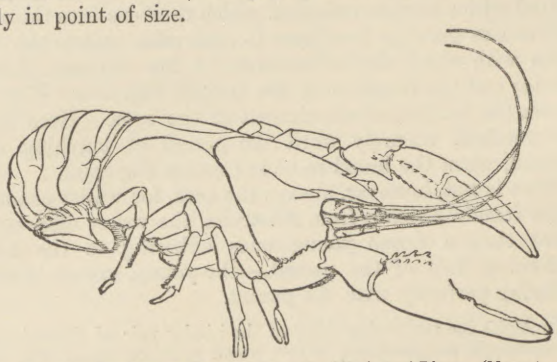


Fig. 25.—Freshwater Cray-fish from the Mississippi River. (Morse.)

The young of the terrestrial Isopoda (*Oniscus*, *Porcellio*, and *Armadillo*) likewise nearly resemble their parents at birth.

In the king-crabs (*Limulus*) the young undergo their principal moults *before* quitting the egg, when they differ but little in aspect from the adult. The metamorphosis undergone by the common lobster appears to be but slight. The young, according to Van Beneden, are distinguished from the adult by having their feet provided like those of *Mysis* with a swimming branch projecting freely outwards, whilst the abdominal and caudal appendages are undeveloped. In nearly all the marine Crustacea the young quit the egg in the condition of *zoëa*. We are acquainted with many examples in all three divisions of the Decapoda.

But we are indebted to Mr C. Spence Bate for the most complete series of observations on the development of one species, the common shore-crab, (*Carcinus mænas*) from the zoëa to the sexually mature animal.[1]

He has shown that in this species the metamorphosis is a perfectly gradual one, and that, dissimilar as is the zoëa when it quits the egg from the adult animal, yet nevertheless the change at each moult is so small that it is only by a comparison between the earliest and the last stages that we perceive the amount of the change which has actually taken place.

"The most important peculiarities," writes Fritz Müller, "which distinguish this zoëa-brood from the adult animal are as follows. The middle body (thorax), with its appendages, those five pairs of feet to which these animals owe their name of Decapoda, is either entirely wanting, or scarcely indicated; the abdomen and tail are destitute of appendages, and the latter consists of a single piece (fig. 26). The mandibles, as in the Insecta, have no palpi. The maxillipeds, of which the third pair is often wanting, are not yet brought into the service of the mouth, but appear in the form of biramose natatory feet. Branchiæ are wanting, or where their first rudiments may be detected as small verruciform prominences, these are dense cell-masses through which the blood does not yet flow, and which have therefore nothing to do with respiration. An interchange of the gases of the water and the blood may (and no doubt does) occur all over the thin-skinned surface of the body; but the lateral parts of the carapace may unhesitatingly be indicated as the chief seat of respiration.

Fig. 26.—Zoëa of Common Shore-crab, *Carinus mænas*, Penn. sp., in its first stage. (Spence Bate.)

"They consist, exactly as described by Leydig in the Daphniæ, of an outer and inner lamina, the space between which is traversed by numerous transverse partitions dilated at their ends; the spaces between these partitions are penetrated by a more abundant flow of blood than occurs anywhere else in the body of the zoëa. A constant current of water passes beneath the carapace from behind forwards, maintained as in the adult animal by a foliaceous appendage from the second pair of maxillæ.

[1] On the development of Decapod Crustacea, *Phil. Trans.*, 1858, pl. xl.-xlvi. p. 589.

"The zoëæ of the crabs are usually distinguished by long, spiniform processes of the carapace (fig. 27). One of these projects up-

Fig. 27.—Zoëa of Common Shore-Crab in its second stage.
r, rostral spine; *s*, dorsal spine; *m*, maxillipeds; *t*, buds of thoracic feet; *a*, abdomen. (Spence Bate.)

wards from the middle of the back, a second downwards from the forehead, and frequently there is a shorter one on each side near the

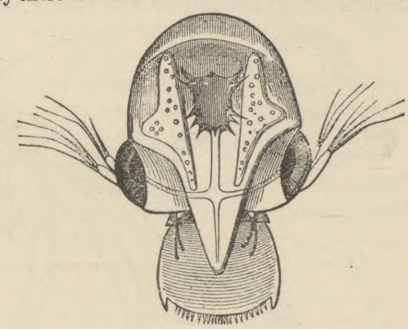


Fig. 29.

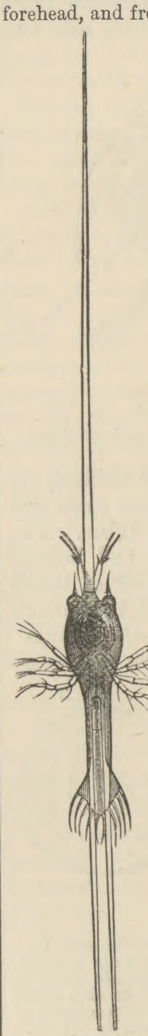


Fig. 28.

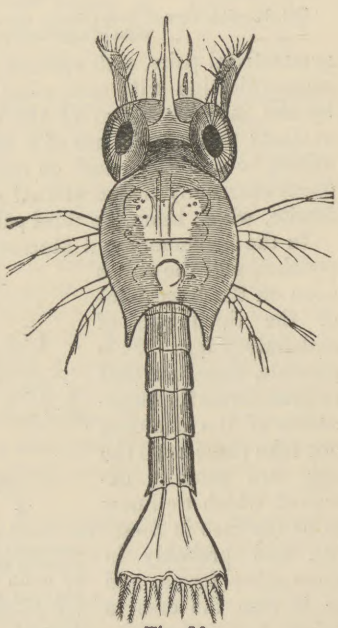


Fig. 30.

Fig. 28.—Zoëa of *Porcellana stellicolla*, F. Müll., mag. 15 diam.
Fig. 29.—Zoëa of *Hippa eremita*, mag. 45 diam.
Fig. 30.—Zoëa of Hermit-Crab, magn. 45 diam. (Fritz Müller.)

posterior inferior angles of the carapace. But in the zoëa of *Maia*, *Eurynome*, and an allied genus to *Achæus*, the spines are wanting in the first two genera, and but of inconsiderable size in the last-named genus.

"The following are the more important peculiarities in the zoëa of the crabs, although less striking than these processes of the carapace, which, in combination with the large eyes, often give them so singular an appearance. The anterior (inner) antennæ are simple, not jointed, and bear two or three olfactory filaments at the extremity; the outer antennæ frequently form a long spine-like process, and bear a minute squamiform process like the antennal scale in prawns. Of the natatory feet (afterwards *maxillipeds*) only two pairs are present, the third is entirely wanting, or present, like the five following pairs of feet, only as minute buds. The tail in zoëa is very variable in form, but nearly always bears three pairs of setæ upon its hinder margin."[1]

When the young zoëa first escapes from the egg, it is enveloped by a membrane veiling the spinous processes of the carapace, the setæ of the feet, and the antennæ; but this is cast off in a few hours. The zoëæ of *Porcellana* (fig. 28) seem to differ widely from true crabs, but really approach them very closely. The dorsal spine is wanting, but the frontal and lateral spines are of extraordinary length, and directed straight forward and backward. The tail bears *five* pairs of setæ.

The zoëa of *Hippa eremita* also resembles that of the crab in general appearance and in mode of locomotion (fig. 29). The carapace has only a short broad frontal process; and the caudal plate is edged with numerous short setæ. The zoëæ of hermit-crabs (fig. 30) have simple antennules like those in the Brachyuran zoëæ. The antennæ bear a scale-like appendage on the outside analogous to that in the prawn. There are only two pairs of well-developed natatory feet (maxillipeds), but the third pair are present in the form of two-jointed rudimentary appendages destitute of setæ. The hinder border of the tail bears five pairs of setæ.

The zoëæ of the shrimps and prawns agree closely with the Anomoura. They have a small median eye between the large compound ones. The third pair of maxillipeds are always present.[2]

In investigating the development of the spiny lobster, Claus found embryos in the ova with completely segmented bodies, but wanting the abdominal and caudal appendages and the last two thoracic somites. They have a single median eye, the anterior antennæ are simple, the posterior have a small secondary branch; the maxillipeds are divided into two branches.[3]

The most singular example of lowly development recorded by Fritz Muller is that of a prawn of the genus *Penæus*.

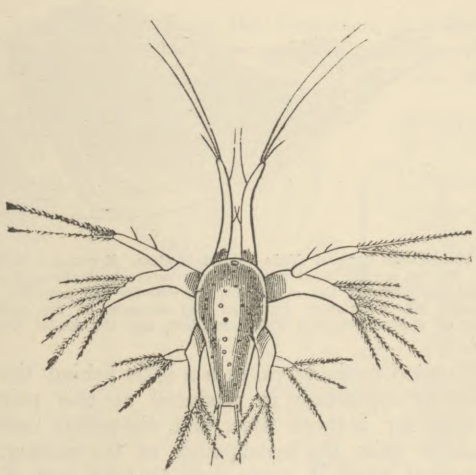
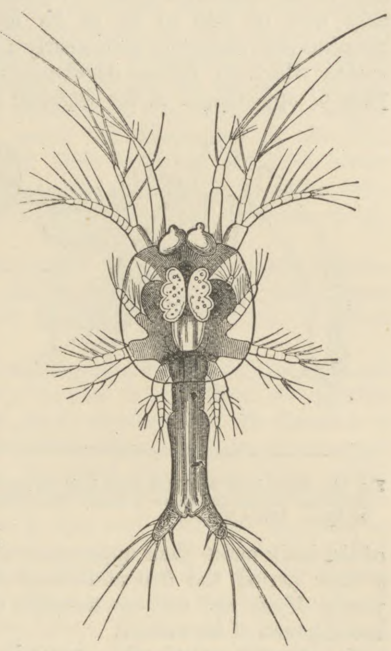


FIG. 31.—Nauplius of a Prawn. Magn. 45 diam. (Fritz Müller.)

The young appear to quit the egg with an unsegmented ovate body, a median frontal eye, and three pairs of natatory feet, of which the anterior pair are simple and the others biramose, agreeing with the larval form common to the lower Crustacea, to which O. F. Müller has given the name of *nauplius*.[4] In this stage there is no trace of a carapace, no trace of paired eyes, no trace of masticating organs, and the mouth itself is overarched by a helmet-like hood. In one of these species the intermediate forms which lead from the nauplius to the prawn have been discovered by Fritz Müller in a nearly continuous series (*op. cit.* p. 57)



32.—Young Zoëa of the same Prawn. Magn. 45 diam. (Fritz Müller.)

After successive moults the nauplius gives place to the zoëa period, during which the paired eyes, the segments of the thorax and abdomen, and the various appendages are produced in bud-like succession. The zoëa next passes into the *mysis*-stage; the antennæ cease to serve for locomotory organs, and their place is taken by the thoracic feet clothed with setæ (fig. 34). The abdomen, furnished with powerful muscles, jerks the animal through the water in a series of lively jumps.

In the case of those Crustacea in which the young, as in *Mysis*, are retained within the incubatory pouch of the parent after quitting the egg, the larva emerges from the egg in a far more rudimentary and destitute condition than in those genera in which no such protective arrangement exists. Van Beneden, whose description of the development of *Mysis* is confirmed by Fritz Müller, mentions the very curious fact that the first segment that makes its appearance is the tail. In other stalk-eyed Crustacea the embryo has the ventral surface of the anterior and posterior halves of the body folded together, and the dorsal surface forms the external convexity of the young animal within the egg; but in *Mysis* the ventral surface is external and convex. The tail soon acquires the furcate form characteristic of the zoëa of the prawn; two thick ensiform appendages next make their appearance at the anterior end of the body, and behind these a pair of

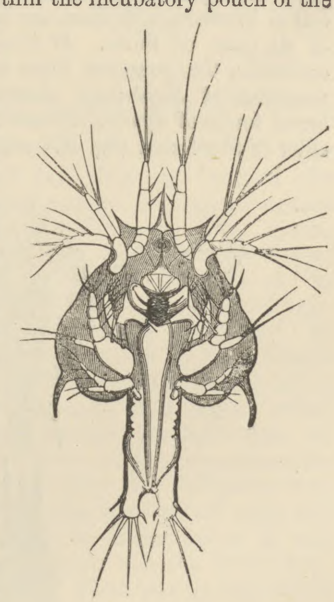


FIG. 33.—Youngest observed Zoëa of another Prawn. The minute buds of a third pair of maxillipeds are visible. The formation of the abdominal segments has commenced. Paired eyes still wanting. Magn. 45 diam. (Fritz Müller.)

[1] Fritz Müller, *Facts and Arguments for Darwin*, pp. 49–52.
[2] Fritz Müller, *op. cit.*, pp. 53–55.
[3] Coste asserts that he has bred young *Phyllosoma* from the ova of *Palinurus vulgaris*, a statement, says Fritz Müller, that requires further proof, especially as the more recent investigations of Claus upon *Phyllosoma* by no means favour this conclusion (Fritz Müller, *op. cit.* p. 57).

[4] Compare fig. 31 with the nauplii of *Apus* and *Artemia*, 5 and 6 of fig. 57, and with that of *Balanus*, fig. 60, A, and fig. 61.

tubercles; these are the antennæ and mandibles. At this immature stage of its development the egg-membrane bursts before any internal organ, or even any tissue except the cells of the cutaneous layer, is formed. The young animal may now be said to be in its nauplius-stage, but its nauplius-skin resembles more nearly a second egg-membrane within which its further development proceeds. The ten pairs of appendages of the cephalic and thoracic divisions

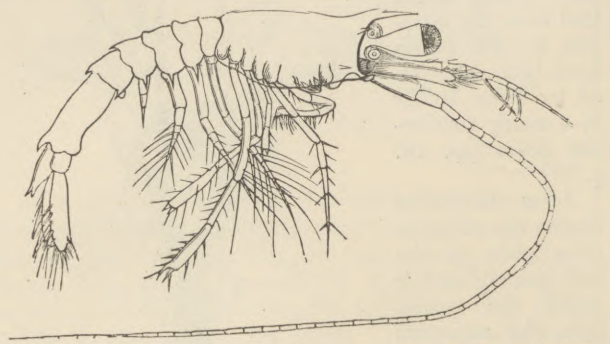


FIG. 34.—Older larva produced from Zoëa represented in fig. 33. The last segment and the last two pairs of feet of the middle-body are wanting. Magn. 20 diam. (Fritz Müller.)

of the body make their appearance simultaneously, and at a later period the five abdominal feet. Soon after the young *Mysis* has cast its nauplius envelope, it leaves the brood-pouch of its mother.

In *Squilla mantis* the eggs do not adhere to the abdominal feet of the parent (which in this genus are branchiferous), but are (says Fritz Müller) deposited in the form of thin, round, yellow plates within its submarine burrow. The spawn is consequently difficult to procure, and quickly dies when removed from its natural hatching-place. In the embryo of *Squilla* the heart is short; the body is long and segmented, but without appendages; the tail is bilobate, and there are indications of the rudiments of six pairs of limbs. If it acquires more limbs before exclusion, the youngest larva must be on a par with the youngest of *Euphausia* observed by Claus. Only two larval forms of *Squilla* are mentioned by Fritz Müller; the elder of these zoëa (fig. 35) resembles the mature *Squilla*,

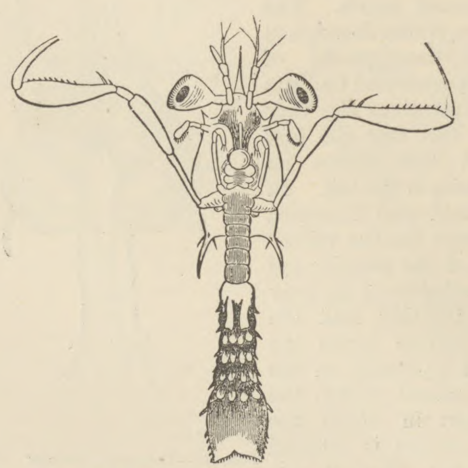


FIG. 35.—Zoëa of a Stomapod, probably *Squilla*. Magn. 15 diam. (Fritz Müller.)

particularly in the structure of the great raptorial thoracic feet and of the last cephalic pair; but the six pairs of feet which follow these are still wanting, although their somites are clearly seen. The abdomen shows rudiments of four pairs of branchial feet and one or two pairs of biramose natatory feet, but the tail has no appendages and still appears as a simple lamina.

The investigations of Goodsir, in 1843,[1] made us acquainted with a most singular family of Crustacea, the *Diastylidæ*, or *Cumaceæ*, which have been placed in the Podophthalmia near to *Mysis*. In general aspect the adult animal presents the most larval and embryonic characters, and might with propriety have been treated as a larval form, had not Goodsir, and subsequently Kröyer, actually taken the young from the brood-pouch of the parent. The antennæ are very small, the thoracic feet are, in most, furnished with setæ; in *Cuma* and *Alauna* the abdominal segments are moniliform and destitute of appendages. The caudal segment bears two long bifurcated styles. In *Bodotria* (fig. 36) five of the abdominal somites

FIG. 36.—Male of *Bodotria*. Magn. 10 diam. (Fritz Müller.)

bear finlets. The young examined by Kröyer, taken from the brood-pouch of the female (which resembles that in *Mysis*), were already one-fourth the length of the parent, which they resembled in every respect. Whether or not there is a considerable development of the young of *Cumaceæ* within the brood-pouch of the parent is not certainly known. In the embryo the caudal portion is bent upwards as in the Isopoda, and the last pair of thoracic feet are wanting.

The development of the Edriophthalmia, or sessile-eyed Crustacea, is more simple than that of the stalk-eyed forms. In the "rock-slater," *Ligia* (fig. 37), the embryo is bent *upwards* within the egg, as in *Mysis*, and has also, like *Mysis*, a larval membrane within which the young *Ligia* is developed. In *Mysis* this larval skin may be compared to a nauplius; in *Ligia*, however, it is destitute of appendages, and resembles a maggot with a long simple tail (fig. 37). The dorsal surface of the young

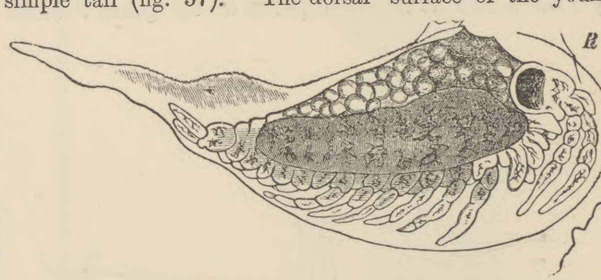


FIG. 37 —Maggot-like larva of *Ligia*. Magn. 15 diam. *R*, remains of egg-membrane. We see on the lower surfaee, from before backwards, the anterior and posterior antennæ, the mandibles, the anterior and posterior maxillæ, maxillipeds, six ambulatory feet, the last segment of the middle-body destitute of appendages, five abdominal feet, and the eaudal feet. (Fritz Müller.)

Ligia is united to the larval skin a little behind the head. A foliaceous appendage is produced at this point, but exists only for a short time, and disappears before the young slater quits the brood-pouch of the mother. The young animal, when it commences to take care of itself, resembles the parent, save that it has only six, instead of seven pairs of ambulatory feet, and the last thoracic somite is but slightly developed and is destitute of appendages. The sexual peculiarities in this as in the young of other Crustacea are not developed at this early period; thus the males lack the hand-like enlargements of the anterior ambulatory feet, and the copulatory appendages are also absent.

The eggs and early stages of *Asellus aquaticus* have

[1] Edinb. *New Phil. Journ.* 1843. See also Bell, *British Stalk-eyed Crustacea*, 1853, pp. 321–333, and Fritz Müller, *Für Darwin*, Engl. trans. p. 81

been investigated by numerous observers. De Geer, Rathke,[1] Spence Bate,[2] and Anton Dohrn[3] have made careful observations on the embryology and development of this abundant freshwater Isopod. As in *Ligia* the embryo is bent upwards within the egg. It quits the egg in a most imperfect state, more so, says Rathke, than any other articulated or vertebrated animal. It is furnished in its earliest stages with two lateral external appendages, which probably are homologous with the foliaceous appendage observed by Fritz Müller at the back of the head in *Ligia*. These zoëal appendages are subsequently moulted. Moreover in the young *Asellus* there are only six leg-bearing segments, and six, instead of seven, pairs of legs as in the adult. The curvature of the embryo upwards, instead of downwards, seems to have been generally observed by Rathke, Dohrn, Fritz Müller, and others. The larval skin is in some genera so closely applied to the egg itself as possibly to be mistaken for an inner egg-membrane. The absence of the last pair of thoracic feet seems also a constant character; all the other limbs are usually well developed in the young of normal Isopods; but in the remarkable and aberrant genus *Tanais* (fig. 38) all the abdominal feet are wanting, but not the caudal appendages; they make their appearance, however, simultaneously with the last pair of the thoracic feet.

Among the many interesting facts relative to the development of the Crustacea not the least remarkable are the series of retrograde metamorphoses which certain Isopods undergo as a consequence of their assuming a parasitic mode

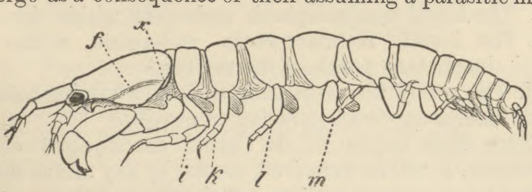


FIG. 38.—*Tanais dubius* (?) Kr. ♀, magnified 25 times, showing the orifice of entrance (*x*) into the cavity overarched by the carapace in which an appendage of the second pair of maxillæ (*f*) plays. On four feet (*i*, *k*, *l*, *m*) are the rudiments of the lamellæ which subsequently form the brood-cavity. (Fritz Müller.)

of life when adult. Thus the *Cymothoa*, or "Fish-lice," which in the adult state live parasitic on fishes, clinging firmly by means of their short recurved hook-like feet, are

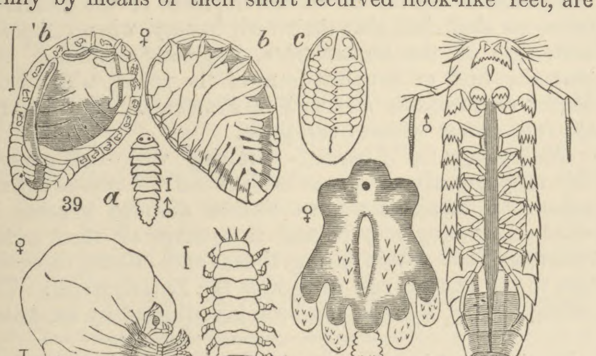


FIG 39.—*Bopyrus squillarum*, Latr. *a*, male; *b'*, female (underside); *b*, the same (dorsal view). (After Spence Bate.)
FIG. 40.—*Phryxus abdominalis*. *a*, the male; *b*, female (ventral aspect). (After Spence Bate.)
FIG. 41.—*Cryptothiria Balani*. *a*, male; *b*, female; *c*, larva. (After Spence Bate.)

lively free-swimming Crustacea in the larval state. Still greater is the metamorphosis which the adult female undergoes in *Bopyrus* (fig. 39), *Phryxus* (fig. 40), *Ione*, *Gyge*, and several other allied genera, which are parasitic on crabs and lobsters, taking up their abode within the branchial cavity. The adult is usually quite destitute of eyes; the antennæ are rudimentary; the broad and flat body is frequently unsymmetrically developed in consequence of the confined space in which it lives; its segments are more or less amalgamated together; the feet are stunted, and the abdominal appendages transformed into foliaceous or highly branched gills. The males are diminutive in size, but usually they have their eyes, antennæ, and feet better preserved than the females; the abdomen is, however, rudimentary, and not unfrequently altogether destitute of appendages.

Among the Isopoda, in the remarkable genera *Cryptothiria*, *Cryptoniscus*, and *Entoniscus*, we meet with forms even still more debased in their adult parasitic condition than *Bopyrus*.

In the case of *Cryptothiria Balani*[4] (fig. 41), first noticed as a male cirripede by Goodsir in 1843, but not rightly determined until 1851, by C. Spence Bate, the female is a large inert seven-lobed fleshy mass, destitute of exserted antennæ, jaws, legs, or branchial appendages, lying within the shell, and attached to the base of the animal of *Balanus balanoides*. The male is free and resembles the male in the *Bopyridæ*; its body is long and slender, and is furnished with seven pairs of legs; it has been met with by Spence Bate, Dana, and other observers within the body-cavity of *Balani*. Here then we have a Crustacean belonging to a higher order, viz., the Isopoda, living parasitic within the shell and deriving its nourishment from one belonging to a lower order, viz., the Cirripedia.

The history of *Cryptothiria pygmæa* (Rathke, sp.) and

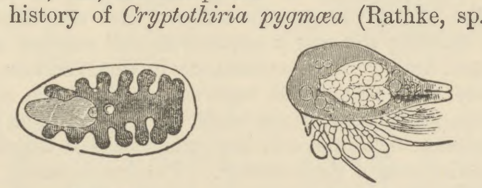


Fig. 42. Fig. 43.

FIG. 42.—*Cryptoniscus planarioïdes*, female. Magn. 3 times. (Fritz Müller.)
FIG. 43.—Embryo of the same. Magn. 90 diam. (Fritz Müller.)

Cryptoniscus planarioïdes (F. Müller) is perhaps still more remarkable. Professor Bell had long ago noticed the frequent presence of a singular parasite on the inner surface of the abdomen of *Portunus* and *Carcinus* on our coasts, having *prima facie* the aspect of a bag of immature eggs. This had been described by Rathke in 1841 as an Entozoarian, but has since been proved by its transformations to be a Cirripede, and was named *Peltogaster*. In 1858 Lilljeborg found what he deemed to be a female *Peltogaster* with an egg-sac; but a careful dissection led to the discovery that another parasite of a higher order, namely a *Cryptothiria*, had become *parasitic upon the parasite*. The most curious part of this super-parasitic history is, that the roots of *Sacculina* and *Peltogaster* (two forms of rhizocephalous Cirripedia parasitic on crabs and hermit-crabs) seem constantly to be made use of by two parasitic Isopods, namely, a *Bopyrus* and the before-mentioned *Cryptoniscus planarioïdes*. These take up their abode beneath the *Sacculina*, and cause it to die away by intercepting the nourishment conveyed by the roots; the roots, however, continue to grow, even without the *Sacculina*, and frequently attain an extraordinary extension, especially when a *Bopyrus* obtains its nourishment from them (Fritz Müller, *op. cit.* p. 94). The free males and the young of *Cryptothiria* and *Cryptoniscus* are unlike young Cirripedes,

[1] *Abhandlungen zur Bildungs und Entwickelungs Geschichte des Menschen und der Thiere* (Leipsic, 1832).
[2] Spence Bate and Westwood, *Hist. Sessile-eyed Crustacea* (1868, vol. ii. p. 346-347).
[3] 'Die embryonale Entwickelung des Asellus aquaticus" (a reprint from *Zeitsch. f. wissensch. Zoologie*, xvii. Bd. ii. Heft 1, Jena, 1866).
[4] C. Spence Bate and J.O. Westwood, *British Sessile-eyed Crustacea* (1868, 8vo. vol. ii. p. 267).

but resemble the young of *Bopyrus*; they are, in fact, larval Isopods.

The female of *Entoniscus* (fig. 44) resides within the body of a species of *Porcellana*, lying in a thin-walled sac between the liver, intestine, and heart of its host, the head being destitute of eyes or antennæ; the thorax has become an irregular inarticulate sac, beset with enormous brood laminæ; the long vermiform and extremely mobile abdomen has sword-shaped legs; and swelling out above it in a globular form, as if in a hernial sac, the heart lies at the base of the first segment. The young of this singular parasite closely resembles that of *Bopyrus* and *Cryptothiria*.

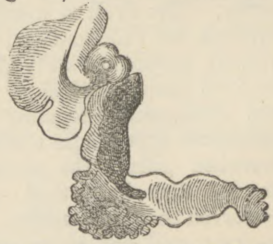


Fig 44.—*Entoniscus cancrorum*, female. Magn. 3 times. (Fritz Müller.)

The embyro of the Amphipoda can be distinguished from that of the Isopoda at a very early period; the former being bent downwards with the dorsal surface external, whilst the latter is bent backwards with the ventral surface external. The embryo in all the genera which have been examined is attached on the anterior part of the back to the inner egg-membrane by a peculiar structure—reminding one of the union of the young Isopoda with the larval membrane, and of the unpaired "adherent organ" on the nape of the Cladocera, so remarkably developed in *Evadne*, and persistent through its life in that genus; but though present in the young of *Daphnia*, it disappears in the adult (Fritz Müller).

The metamorphosis of the young Amphipod after it quits the egg seems greatly reduced and simplified, for before quitting the egg it acquires its full number of segments and limbs.[1] In those instances in which certain of the segments are amalgamated together, or where one or more segments are deficient in the adult, we find the same fusion and the same deficiencies in the young animals taken from the brood-pouch of their mother. The development of the Hyperiidæ, an oceanic group of Amphipods found only in the gill-cavities of the *Medusæ*, is very exceptional and remarkable. Thus, in *Hyperia* the youngest larvæ, taken by Fritz Müller from the brood-pouch of the mother, already possessed the whole of the thoracic feet; on the other hand, those of the abdomen were not as yet developed. All the feet are at first simple, but soon become converted into highly denticulated prehensile feet. In this state they remain for a very long time,—the abdominal appendages growing into powerful natatory organs, whilst the eyes, at first wanting or very minute, expand into large hemispheres occupying the entire lateral, and even encroaching upon the dorsal and frontal walls of the head. The females (*Hyperia*) are distinguished by a very broad thorax, and the males (*Lestrigonus*) by their long antennæ. The youngest larvæ cannot swim, but are provided with chelate feet (as shown by Spence Bate) by which they cling firmly to the swimming-laminæ of their host. The feet of the adults are simple, but they are then excellent swimmers, and are not unfrequently met with free in the open sea. The diversity in structure of the antennæ in the adult male and female Hyperiidæ is so great as to have led naturalists to place them in separate genera or even families; but this difference is developed only when the animals are full-grown. Up to this period the young of both sexes resemble the females. In the male shore-hoppers (*Orchestia*) the second pair of the anterior feet is provided with a powerful hand (fig. 45), as

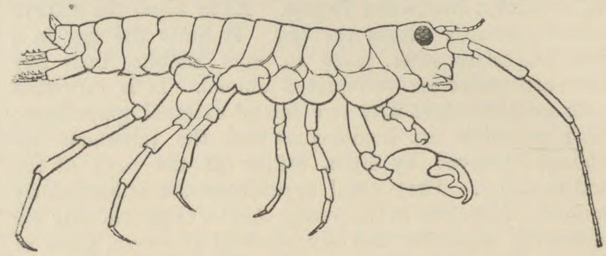


Fig. 45.—*Orchestia Darwinii*, n. sp. male. (Fritz Müller.)

in the majority of Amphipoda, but quite different from the female; the young nevertheless resemble the female. This is also the case in the adult male in *Limulus*, in which the second pair of appendages (antennæ) are peculiarly modified (see 3*a* in fig. 12 above); but in the young male they exactly resemble those of the adult female. According to Spence Bate and Fritz Müller, this second pair of antennæ are absent in the females of *Brachyscelus*, although the male possesses them, like other Amphipods.

In the foregoing brief sketch of the evolution of the young in the Malacostraca, it will be perceived that certain lines of development are followed, but these are subject to great diversity, and often vary greatly in the same order.[2] Thus we have :—

I. The larval metamorphosis undergone within the egg.[3]
II. The larval metamorphosis undergone within the incubatory pouch of the mother.[4]
III. The young first appearing as free-swimming *zoëæ*.[5]
IV. The young first appearing as *nauplii*.[6]

These four stages in the larval development of the Crustaceæ, it will be perceived, are not by any means strictly confined to particular orders of the Malacostraca, nor do they hold good for all the members of the group in which they have been observed to occur. There is, in fact, no "hard and fast" rule in the class, but on the contrary, there would appear to be numerous exceptions and variations in every group.

In considering the larval development of the Entomostraca, we shall find that their early history, when compared with that of the Malacostraca, is greatly simplified, and that the first or nauplius form of the young, which Fritz Müller *exceptionally* met with in *Penæus*,[7] has now become the rule almost without exception.

Embryology of Limulus.—Starting with that remarkable representative of a most ancient and now almost extinct order, the Merostomata, we find in *Limulus* a genus in which the young may be said to undergo all their earlier metamorphoses within the egg, thus at once offering an exception to the general rule as regards the Entomostraca. The embryology of *Limulus* has been investigated by Dr Anton

[1] "Even peculiarities in the structure of the limbs, so far as they are common to both sexes, are usually well marked in the newly-hatched young, so that the latter generally differ from their parents only by their stouter form, the smaller number of the antennal joints and olfactory filaments, and also of the setæ and teeth with which the body or feet are armed, and perhaps by the comparatively larger size of the secondary flagellum" (Fritz Müller, *Für Darwin*, Engl. trans. p. 76)

[2] In the normal Isopoda, as we have seen, the development of the young is one of progress to the adult; but in the parasitic forms the young animal before attaining the adult state actually has to undergo a retrograde metamorphosis.

[3] An instance of this occurs in the Decapoda-Brachyura, viz., *Gecarcinus* (J. O. Westwood); in the Anomoura, *Dromia* (H. Woodward; in the Macroura, *Potamobius* (*Astacus*) *fluviatilis* (Rathke). In the Amphipoda the young appear to have always acquired their full number of segments and appendages before quitting the egg (Fritz Müller, Spence Bate, &c.)

[4] In the Stomapoda by *Mysis*, and *Cumaceæ* (?); in the Isopoda by *Asellus*, *Ligia*, &c.

[5] In the Decapoda-Brachyura by *Carcinus* (Spence Bate), by *Cyclograpsus* and many other crabs and lobsters (Fritz Müller).

[6] In the Decapoda-Brachyura by a prawn near to *Penæus* (Fritz Müller).

[7] It is very desirable that this remarkable and isolated case in the development of the Macrouran Decapod should be confirmed by others.

Dohrn[1] and Dr A. S. Packard.[2] The natural history of the king-crab has been studied by the Rev. Samuel Lockwood,[3] and its anatomy has quite recently formed the subject of two elaborate memoirs by Professor Owen,[4] and by Dr Alphonse Milne-Edwards.[5]

We can only very briefly notice these important contributions to our knowledge of the Xiphosura here.

The female *Limulus* of the north-east American coast spawns twice every year during the months of May, June, or July,[6] at the great high tides. It comes up to near high-water mark, spawning under water; thus the eggs are

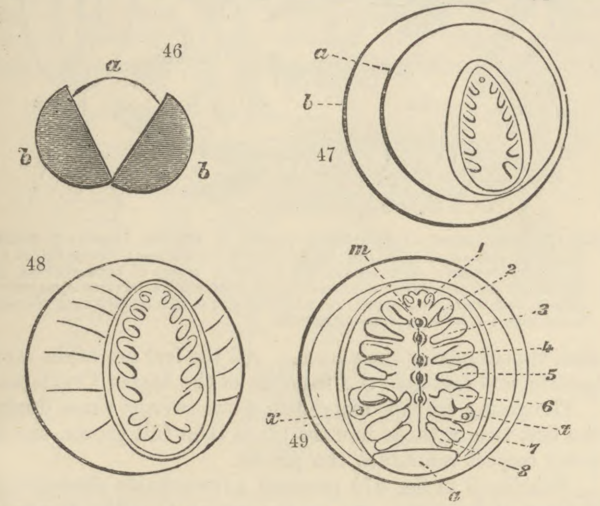


FIG. 46.[7]—Egg of *Limulus polyphemus*: *a*, protoderm; *b*, the chorion (after Dohrn).
FIG. 47.—Third stage in the embryo of *Limulus*: *a*, protoderm; *b*, chorion (after Packard).
FIG. 48.—Fourth stage (?) in the embryo of *Limulus* (after Dr. Packard's figure).
FIG. 49.—Fourth stage (?) in the embryo of *Limulus*: 1, antennule; 2, antenna; 3-6, maxillipedes; 7 and 8, thoracic plates afterwards bearing the branchiæ; *m*, the mouth; *x*, the ovarian apertures (?); *a*, the abdomen (after Dohrn).

daily exposed to the sun's warmth for a short time at low water. Great numbers arrive in pairs, the male grasping the sides of the shield of the female with his strong and peculiarly modified chelate antennæ. The eggs are deposited by the female in a hole in the sand, and are fecundated by the male after deposition, and are then left to hatch. Only one other similar case is on record, namely, that of the common freshwater cray-fish, in which, according to M. Chantran, the eggs are fecundated after expulsion from the oviducts. The eggs occupy from fifty to seventy days in hatching, according to the favourable or unfavourable conditions under which they are deposited; some which Dr Lockwood set aside in a jar of sea-water in a dark place hatched after 350 days!

The egg has two membranes, a dense inelastic chorion and an inner elastic protoderm.[8] This chorion remains entire so long as development is arrested or is sluggish, but as soon as the embryo increases in size, the tough chorion splits asunder, and the inner elastic protoderm enlarges, becomes dense, and vicariously fulfils the duties of the former (fig. 46).

A similar splitting of the external egg-membrane has been noticed in *Apus*. Fritz Müller points out that in some Isopoda (as for instance *Philoscia*) the larval skin is not only without any folds or sac-like diverticula, but is closely applied to the egg-membrane. This second egg-membrane in *Limulus* may perhaps therefore correspond to this first larval skin. Certainly, when the embryo first appears, its position is the same as in *Asellus*, *Ligia*, *Philoscia*, and other Isopods, *i.e.*, with its ventral sur-

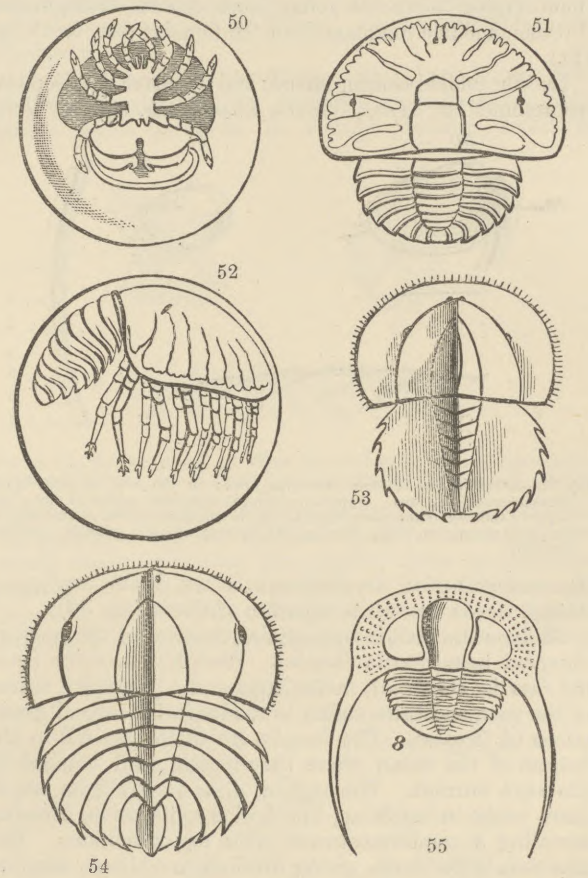


FIG. 50.—Fifth stage (?) of embryo of *Limulus* (after Dohrn). At this stage the chorion is split, and the protoderm is expanded by the admission of water by endosmose, in which the embryo is seen to revolve.
FIG. 51.—Ninth stage (?) of embryo, "just before hatching" (after Packard); dorsal aspect.
FIG. 52.—The same: side view of embryo.
FIG. 53.—Larva of *Limulus* recently hatched (after Packard).
FIG. 54.—Larva of *Limulus* on hatching (the "*Trilobitenstadium*" of Dohrn).
FIG. 55.—*Trinucleus ornatus*, Sternb.; adult specimen with six thoracic segments and fully-developed genal spines.

face convex (figs. 47 and 48). In its first stage the larval *Limulus* has six bud-like indications on each side of the mesial line, where the paired *cephalic* appendages will be developed (fig. 47). In later stages (figs. 48–52) we have first two, then more, up to six pairs, of *thoracic* natatory feet (which in the adult become branchiferous), and traces of as many as nine post-cephalic somites, but the last three never attain appendages. As the young *Limulus* increases in size, the yolk gradually becomes absorbed, and the larva assumes the position of an Amphipod in the egg, having its dorsal surface convex, instead of its ventral, which is now concave (fig. 52). There appears to be no stage seen in larval *Limulus* which can be compared with the nauplius stage of *Apus* (as Dr Packard has supposed).[9] The

[1] "Zur Embryologie und Morphologie des *Limulus polyphemus*," in *Jenaischen Zeitschrift*, Band vi. Heft 4, Taf. xiv. and xv., 1871.

[2] "The Development of *Limulus polyphemus*," by A. S. Packard, in *Memoirs of Boston Soc. Nat. Hist.* 1871, vol. ii. pp. 155–202, pl. 3–5.

[3] "The Horse-Foot Crab," by the Rev. S. Lockwood, in *American Naturalist*, 1870, vol. iv. p. 257.

[4] "Anatomy of the American King-Crab," by Prof. Owen, in *Trans. Linn. Soc.* 1872, vol. xxviii. pp. 459–506, pl. 36–39.

[5] *Etudes sur les Xiphosures et les Crustacés de la Region Mexicaine*, par Alph. Milne-Edwards (Paris, 1873, folio. pp. 43. pl. 1–12).

[6] These investigations are confined to the American king-crab, and were made at Raritan Bay, New Jersey. Van der Hoeven's memoir on Limulus was written on the East Indian *Limulus moluccanus* (*Rech. sur l'Hist. Nat. et Anatom. des Limules*, fol. 1838, Leyden, p. 48, plates 1–7).

[7] Figs. 46–55 are from H. Woodward's paper on the "Relationship of the Xiphosura to the Eurypterida, &c.," *Quart. Journ. Geol. Soc.* 1872, vol. xxviii. p. 50.

[8] Dohrn calls the inner membrane in the egg of Limulus the "chorion" and the outer the exochorion, but Packard's term "protoderm" appears preferable for the former.

[9] Packard, *op. cit.* p. 163.

Trilobiten stadium of Dohrn[1] resembles *Prestwichia rotundata* from the Coal-measures far more than any known Trilobite. Packard has figured an earlier (?) stage of *Limulus* than Dohrn's "Trilobiten-stadium," which much more nearly resembles *Trinucleus*[2] (compare figs. 51 and 55).

In its earlier stages the young *Limulus* can roll its posterior segments under its head-shield, and when it at last leaves the egg it can swim well, and has been captured by Alexander Agassiz, swimming freely on the surface of the ocean, three miles from Naushon Island, Buzzard's Bay.[3] At this period it has no caudal spine or telson; this is acquired only at a later moult, whilst a year or more elapses before the young males can be distinguished by their modified antennæ from the females (see 3*a* in fig. 12).

In the shield-bearing, naked, and bivalved Phyllopoda, represented by *Apus*, *Nebalia*, *Branchipus*, and *Estheria*,

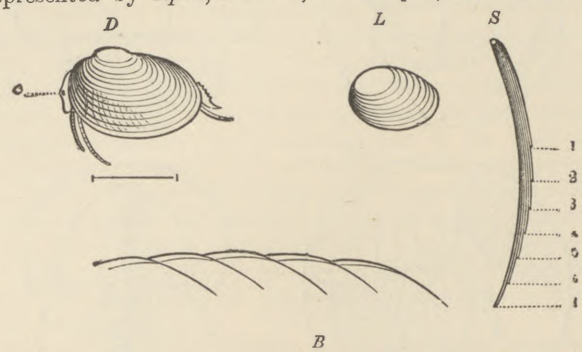


FIG 56.—*Estheria*, sp. *D*, from Dubuque, Iowa; (*e*) the eye. *L*, from Lynn, Massachusetts (nat. size). *S* presents a highly magnified section of one of the valves to show the successive moults. *B*, an enlarged portion of the edge of the shell along the back, showing the overlap of each growth. (Morse's *Zoology*).

the embryological development is no doubt analogous, though less is known in regard to *Estheria* (fig. 56).

In *Apus* the male is not certainly known, all the progeny observed being fertile females. Probably, however (as is the case in *Daphnia*), males appear at a particular season of the year, and these suffice to render fertile several generations of females. The females let their eggs fall to the bottom of the water, where they remain until hatched by the sun's warmth. The eggs of *Apus* occupy from two to there weeks in hatching; the chorion splits, as in *Limulus*, revealing a semi-transparent inner egg-membrane. This also soon after bursts, giving freedom to a simple nauplius like that exceptionally met with by Fritz Müller in a prawn allied to *Penœus*. The large cephalic shield, so characteristic of the adult *Apus*, is not seen in these early stages, and when it first appears, it closely resembles that of *Peltocaris*, an extinct Silurian form (4 in fig. 57). The nauplius, being short-bodied, does not display those graceful undulatory motions in the water observed in the adult, but progresses rather by a series of jerks like the adult *Cyclops*. At the end of eight or ten days the young Phyllopod has acquired considerable size. The body-segments and feet, so numerous in *Apus*, *Artemia*, and *Branchipus* (5*a* in fig. 57), are formed gradually (in repeated moults) from before backwards, without any sharply-defined regions of the body being discernible either by the time of

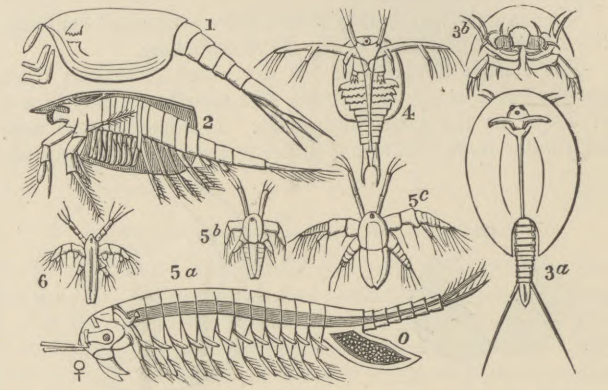


FIG. 57.—PHYLLOPODA.—1, *Ceratiocaris papilio*, U. Silurian, Lanark; 2, *Nebalia bipes* (one side of carapace removed to show branchial feet), Marine British; 3, *Lepidurus Angassi*: *a*, dorsal aspect; *b*, ventral aspect of head showing the hypostome and mandibles; hab. freshwater, Australia; 4, larva of *Apus cancriformis*; 5, *Branchipus stagnalis*: *a*, adult female; *b*, first larval stage; *c*, second larval stage; 6, larva of *Artemia salina*.

their appearance or their form. All the feet are of the same pattern, and resemble the maxillæ of the higher Crustacea.[4]

The young animal exuviates about twenty times during the first two or three months; it is then full grown, and in every respect resembles the parent.

Nebalia (2 in fig. 57) presents a remarkable exception to the rest of its order, the young apparently (like *Daphnia*) undergoing no metamorphosis after they quit the egg. Metschikoff, who has recently studied the development of *Nebalia*, states that he has observed that it passes through both a nauplius and a zoëa stage within the egg,[5] and he therefore regards *Nebalia* as a Phyllopodiform Decapod. We hardly see sufficient grounds at present for assigning *Nebalia* to a higher order than that in which it is now placed.

The Cladocera do not afford any additional aid in embryological research. They appear to quit the egg only smaller than the parent, but with their full number of limbs.

Of the developmental history of the Ostracoda but little is known. Zenker states that their anterior limbs are developed first, and the youngest stages, according to Claus, are shell-bearing nauplius-forms.

In the Copepoda (3–7 in fig. 58), the buckler does not cover more than the head and thorax, the abdominal segments, which are nearly cylindrical, extending beyond it. They are met with both in fresh waters and in the sea all over the world, and are most numerously represented both in a free state and as parasites. The larvæ of the non-parasitic forms (3*b*–*d* in fig. 58), all possess at the earliest period the three anterior pairs of limbs, *i.e.*, the future antennæ and

[1] Dohrn, *op. cit.* p. 639, Taf. xv. fig. 4.

[2] Salter supposes (*Quart. Journ. Geol. Soc.*, vol. iii., 1847, p. 252) that the membranous margin of the head-shield of *Trinucleus* was once entire, "then became plicate, then perforate, and lastly separated into linear processes." It seems more probable that the margin of the head-shield was originally digitate, then gradually closed up, leaving only perforations along the sutures in some, and only plicæ in others. We have an analogous case in *Haliotis*, *Scissurella*, and *Pleurotomaria* amongst the Mollusca, in which a slit becomes partially or wholly closed up, leaving perforations at intervals. In the Mollusca it is connected with the respiratory functions, but in *Limulus*, *Hemiaspis*, and *Trinucleus* it is probably a remnant of the margins of the *primitive* segments which have coalesced to form the cephalic shield.

[3] Packard, *op. cit.* p. 155.

[4] "The maxilla of the Decapod larva is a sort of Phyllopodal foot" Claus). "We might," says Fritz Müller, "regard the Phyllopoda as zoeæ which have not arrived at the formation of a specialized thorax or abdomen, but have instead repeatedly reproduced the appendages which first follow the nauplius limb." The present writer has compared the Decapod larva in which the maxillæ serve temporarily as organs of natation and locomotion with the similar appendages which *persistently* fulfil this office in *Pterygotus*, *Stylonurus*, and *Limulus* (H. Woodward, *Mon. Pal. Soc. Merostomata*).

[5] The greatest caution should be exercised in instituting comparisons between the so-called "nauplius" and "zoëa" stages of any one Crustacean, when such stages are passed *within* the egg, and those of any other Crustacean whose young actually pass through such stages *after they have quitted the egg*. In the Decapoda we at present know of *only one instance* in which the young appears as a free-swimming *nauplius*; in the majority we see *only the zoëal and larval* stages; in some even the zoëal stage is overleaped, and the young appears as a larva differing but little, if at all, from the parent.

mandibles,—the anterior pair with a single joint, the two following pairs being bifurcate. The eye is single, and the labrum and mouth already occupy their permanent positions. The hinder body is short, the abdominal segments not being yet developed. In subsequent moults these posterior segments appear, and new limbs sprout forth. In the second stage a fourth pair of extremities is added; these are the future maxillæ; then follow three new pairs of limbs, the maxillæ, and two anterior pairs of natatory feet. The three anterior pairs of appendages still represent rowing-feet. At the next moult the first cyclops-stage is arrived at, when there is a resemblance to the adult in the structure of the antennæ and buccal organs, but the number of body-segments and appendages is

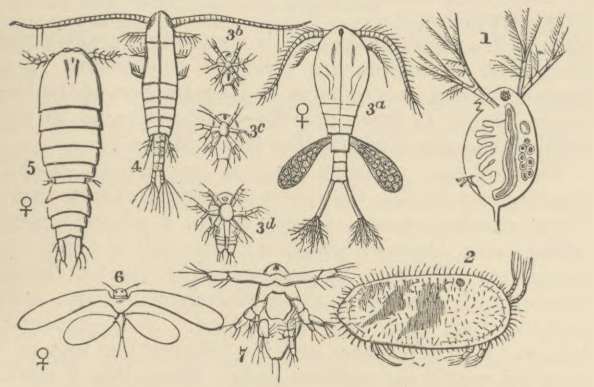


Fig. 58.—(1) Cladocera, (2) Ostracoda, (3-7) Copepoda. 1, *Daphnia pulex*, freshwater, near London. 2, *Candona hispida*, freshwater, near London. 3, *Cyclops quadricornis*: *a*, ♀, adult with eggs; *b*, *c*, *d*, three stages of development of nauplius. 4, *Cetochilus septentrionalis*, Firth of Forth. 5, *Sapphirina ovatolanceolata*, Dana, ♀, Atlantic, off harbour of Rio Janeiro. 6, *Nicothoe astaci*, ♀, with egg-sacs (from gills of common Lobsters, London Market). 7, Nauplius of Copepod. (After Fritz Müller.)

still much less than in the parent. Only the rudiments of the third and fourth pairs of natatory feet are seen, and the body is made up of an oval cephalothorax, the second, third, and fourth thoracic segments, and an elongated terminal joint. In the *Cyclopidæ* the posterior antennæ have lost their secondary branch, and the mandibles have completely thrown off the previously existing character of natatory feet; whilst in other families these appendages are persistent, although more or less altered. Many of the parasitic Copepoda do not pass beyond this stage of free development. Such forms as *Lernanthropus* and *Chondracanthus* never acquire the third and fourth pairs of limbs, nor does the fifth thoracic somite separate from the abdomen. Others, such as *Achtheres*, even fall to a still lower grade, by the subsequent loss of the two pairs of natatory feet. But all free Copepoda and most of the parasitic Crustacea pass through a longer or shorter series of stages of development, in which the limbs acquire a higher degree of division into joints in continuous sequence, the posterior pairs of feet are developed, and the last thoracic segment and the different abdominal segments are successively separated from the common terminal portion (Claus). Some parasitic Copepods, such as *Achtheres percarum*, certainly quit the egg like the rest in the nauplius-stage; the oval astomatous body bears two pairs of simple rowing feet, and behind these are two inflations marking the third pair, each having a long seta. Beneath this nauplius-skin a very different larva lies concealed, which in a few hours bursts its clumsy envelope, and makes its appearance in a form which agrees both in the segmentation of its body and the development of its extremities with the first cyclops-stage. The entire series of nauplius-stages which are passed through by the free Copepods are in this case completely overleapt.

Although the parasitic species of Copepoda are all more or less permanently fixed when adult, they pass their youthful stages as freely locomotive larvæ. To this rule there is a singular exception in the genus *Caligus*. The young animal (described by Burmeister as a peculiar genus, *Chalimus*) lies at anchor upon a fish by means of a cable springing from its forehead, and having its extremity firmly seated in the skin of the fish. When sexual maturity is attained the cable is cut, and the adult *Caligus*, which is an admirable swimmer, is not unfrequently captured swimming freely in the sea (Fritz Müller).

The animals belonging to the last division comprise two orders, the Rhizocephala and the Cirripedia. They have long been kept distinct from the Crustacea, and, together with various parasitic forms of Copepoda, whose developmental history was not known, classed as Epizoa and Cirripedia.

By later zoologists the Rhizocephala have been placed with the Pœcilopoda, but as this division includes many genera which prove to be merely parasitic forms of

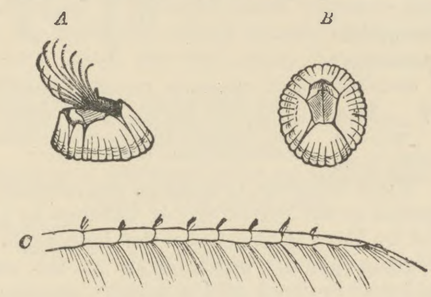


Fig. 59.—*A*, *Balanus* (young), side view with cirri protruded. *B*, upper surfac of same; valves closed. *C*, highly magnified view of one of the cirri. (Morse.)

Copepoda, it will be more convenient to separate them. All the animals of this last division, which for convenience we would designate under the general name of Anchoracephala, are attached when adult;—in the Cirripedia by means of cement ducts which deposit calcareous matter, forming in the adult *Balanidæ* (figs. 59–60) a broad shelly

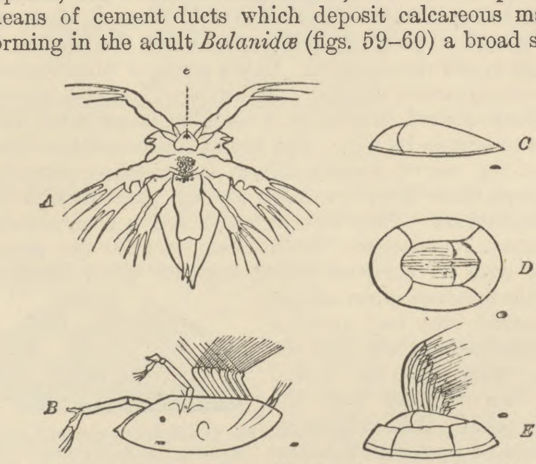


Fig. 60.—Early stages of *Balanus*. *A*, Nauplius; *e*, eye. *B*, Larva with a bivalve shell and just before becoming attached (represented feet upwards for comparison with *E*, where it is attached). *C*, After becoming attached, side views. *D*, Later stage, viewed from above. *E*, Side view, later stage and with cirri extended. The dots indicate the actual size. (After Spence Bate.)

base, and a simple attachment in the pedunculated *Lepadidæ*; in the Rhizocephala by ramifying nutritive roots, which sink deep into the interior of the body of the animal upon which they become parasitic (see figs. 82 and 83, p. 665). In all the members of this division the young appear as naupliiform larvæ [1] which speedily moult their first coat. The body is unsegmented and pyriform, having a median eye,[2] a first

[1] See Mr C. Spence Bate's Memoir, *Annals and Mag. Nat. Hist.* 1851, 2d series, vol. viii. p. 324, plates 6, 7, 8.

[2] In *Sacculina purpurea* and in some species of *Lepas* the median eye is wanting.

pair of minute antennæ, two anterior horns, which inclose the second pair of antennæ,[1] one pair of uniramous and two pairs of biramous natatory legs, a forked terminal projection to the body, and a posterior point to the carapace (see fig. 60 A, and fig. 61).

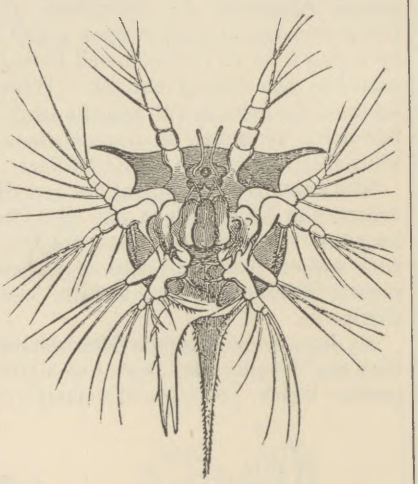


Fig. 61.—Nauplius of *Tetraclita porosa* after the first moult. Magn. 90 diam. The brain is seen surrounding the eye, and from it the olfactory filaments issue. Behind it are some delicate muscles passing to the buccal hood. (Fritz Müller.)

The nauplii of the Anchoracephala are distinguished from the Copepoda by possessing a dorsal shield or carapace, which sometimes, as in *Sacculina purpurea*, projects far beyond the body all round. They are also further distinguished by possessing a pair of so-called "olfactory filaments," which spring directly from the head. These filaments, or horns of the carapace (which are interpreted as the second pair of antennæ by Darwin), are believed by Fritz Müller to be the homologue of the so-called "green gland," which opens at the end of a conical process at the base of the inferior antennæ in the Decapoda, and of the conical process, with an efferent duct traversing it, seen on the inferior antennæ of the Amphipoda.

The abdomen of the young Cirripede is produced into a long tail-like furcate extremity, that of the young in Rhizocephala into a movable caudal fork.

The young Cirripedes have a mouth, stomach, &c., and their posterior pairs of limbs are fitted for organs of prehension and manducation. In the young of Rhizocephala all these organs are wanting. The young Cirripede, having to undergo several moults as a nauplius, is provided with organs to sustain its life. The young Rhizocephalon being astomatous, cannot sustain life in its nauplius state for long, and must therefore more rapidly pass through its transformations. They both at length arrive at an equally astomatous *pupa*-stage. In this stage we see the young animal with its carapace folded together like a bivalved shell; the foremost limbs become transformed into very peculiar adherent feet, and the two following pairs, like the frontal horns, are cast off with the nauplius-skin. Behind these are six pairs of powerful biramose natatory feet, with long setæ and two short setigerous caudal appendages. The young pupæ of the Rhizocephala and Cirripedia agree in every particular, save that the latter possesses a pair of composite eyes; sometimes also traces of the frontal horns seem to persist.

Fig. 62.—Pupa of a Balanide (*Chthamalus?*). Magn. 50 diam. The adherent feet are retracted within the rather opaque anterior part of the shell. (Fritz Müller.)

When the proper time arrives the pupæ of the Cirripedia attach themselves by means of their prehensile antennæ to rocks, shells, turtles, cetacea, drift-wood, ships, &c.; the carapace becomes converted into the peculiar sessile-shell of the *Balanus*, or the pedunculated *Lepas*; the natatory feet grow into long cirri by which nourishment is whirled to the mouth, now open and furnished with mandibles and maxillæ. The pupæ of Rhizocephala in like manner attach themselves to the abdomen of crabs, *Porcellanæ*, and hermit-crabs; but they remain astomatous, lose all their limbs completely, and appear as sausage-like, sack-shaped, or discoidal excrescences upon their host, filled with ova (figs. 82 and 83); from the point of attachment closed tubes, ramifying like roots, sink deep into the interior of the host, twisting around the intestine, or are diffused among the sac-like tubes of the liver. The only manifestations of life which persist in this most retrogressively metamorphosed Crustacean are powerful contractions of the roots and alternate expansion and contraction of the body, causing water to flow into the brood-cavity, to be again expelled through a wide orifice (Fritz Müller).

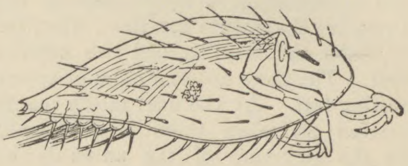


Fig. 63.—Pupa of *Sacculina purpurea*. Magn. 180 diam. The filaments on the adherent feet may be the commencements of the future roots. (Fritz Müller.)

Darwin has recorded various anomalous cases of development in the Cirripedia; amongst others, that of *Cryptophialus minutus* (which forms a separate section Abdominalia, Darwin), parasitic in the shell of *Concholepas peruviana*. The egg, at first elliptical, becomes broader anteriorly, then acquires three club-shaped horns, one at each anterior angle and one behind. Subsequently the posterior horn disappears, and the adherent feet may be recognized within the anterior ones. From this "egg-like larva" the pupa is directly produced. Its carapace is but slightly compressed laterally, and is hairy as in *Sacculina purpurea*; the adherent feet are large, the natatory feet wanting, as are also the corresponding cirri in the adult animal. Mr Spence Bate mentions a similar case in a Rhizocephalon, in which the nauplius-stage is overleaped and the young quits the eggs as a pupa-form larva.

Exuviation in the Adult and Reparation of Injuries.—As we have already seen, the young Crustacean, on quitting the egg, usually undergoes a series of larval metamorphoses more or less numerous, and subject to considerable variation even among closely-allied forms. Eventually, whether by a direct or an indirect route, a form is attained in all, which, save in size, closely agrees with the adult.

Amongst the Insecta the larva usually undergoes repeated moults during its growth, from the time when it first quits the egg until it reaches the pupa-stage, a period of rest in most, but not in all insects,[2] and an astomatous stage in some larval Crustacea.[3] From the pupa springs the *full-grown* and perfect insect, when no further moult or change takes place—indeed, in some insects the parent only lives to deposit its eggs, and then dies. The immature Crustacean, in passing through its nauplial and zoëal stages, may moult its skin seven or eight times, or even more; nevertheless, when it reaches the *imago* stage, it has not nearly attained the size of the adult parent, but continues to grow and cast its calcareous envelope as often as its increased size necessitates its so doing. When adult, it

[1] "Olfactory filaments" (Fritz Müller).

[2] The aquatic pupa of the dragon-fly is active and predaceous.

[3] The pupæ of Rhizocephala and Cirripedia are both astomatous.

[4] *Imago.*—Darwin has applied the term "pupa-stage" to the free-swimming astomatous larva in the Cirripedia previous to its settling down, casting off its pupa-coat, and becoming adult. The writer has long doubted if the Crustacea ever really arrive at this highest or *imago* condition, and whether they are not always in a "pupa-period" all their lives. The larval *Aphis*—the branchiated *Axolotl*—are but arrested stages of development of more advanced forms, but they deposit eggs, and in the case of the *Axolotl* they possess all the attributes of the perfect animal, save the persistent external larval branchiæ.

still continues to moult probably through its entire lifetime, even to extreme old age.[1]

In casting its shell a crab not only parts with every joint and plate of its limbs and carapace, of its long and slender antennæ, its external eyestalks, the plates of the tail, the appendages of the mouth, the lining of its gills, but even its stomach, with the gastric teeth and the slender apodemata, which give support to the muscles of the limbs and body—so that when the crab has escaped from its old suit, the cast-off shell seems nearly as perfect as the animal itself

When exuviating, the crab and lobster both escape from their old shells by a line of dehiscence which opens between the posterior border of the carapace and its union with the abdomen. Professor Bell also states that in the great crab (*Cancer pagurus*) and some other forms, the carapace divides at the junction of the epimera with the dorsal piece or tergum.

In *Limulus* the carapace splits all round the anterior border, at the union of the dorsal and ventral walls. *Limulus* sheds its shell five to six times during the first year, and probably once annually after that period.

Sir John Dalyell, Mr Couch, Mr Gosse, Mr Spence Bate, Mr Warrington, and others, have given excellent accounts of the process of moulting of various Crustacea. An accurate observer, Mr Harper, states[2] that he confined six small specimens of the common shore-crab (*Carcinus mœnas*) in separate glasses, and fed them daily, until one of them showed that something was amiss by refusing food. Soon after it cast its shell, an operation which only occupied five minutes. When very young this crab moults frequently. The same author registered the dates, and preserved the exuviæ of one which moulted on April 11, 1858, and on May 22, July 3, August 30, and September 26 of the same year; the acceleration of the last moult is attributed to the creature having been fed daily, "like a prize beast," on purpose to try the effect on its growth. Some of these little crabs had lost part of their limbs, but after a moult new limbs appeared of very diminutive size; after a second moult each new limb had increased to one-half as large as the rest, and in the third moult it had reached to its proper bulk and form. Hermit-crabs shed their hard shell before pulling off the exuviæ of the tail; their increase at each moult is much less rapid than in the common crab. Prawns exuviate more frequently. Mr Warrington saw the change occur with much regularity every twelve days in the summer season. With the exception then of certain parasitic forms of Crustacea, which, like the Rhizocephala, have undergone such a complete retrograde metamorphism that no trace of articulations or appendages remain, all the Crustacea periodically exuviate their dermal covering, whether calcareous, chitinous, or membranaceous. In the Cirripedia it would not be possible to exuviate the adherent shell of the adult *Balanus*, or the peduncle of *Lepas* or *Scalpellum*, but, even in this aberrant division, the lining membrane of the shell and the many-jointed cirri are regularly moulted.[3]

It has long been known that Crustacea possess the power of voluntarily casting their limbs, and of restoring such as have thus been lost by the animal's will or by accident.[4] If one or more distant phalanges of a limb be torn off, the animal has the power to throw off the remaining part of the limb also. This separation always occurs near the basal extremity of the first phalanx. When the limb is thrown off, the blood-vessels and nerve retract, thus leaving a small cavity; from this the germ of the future leg springs, and is at first seen as a nucleated cell. A cicatrix forms over the raw surface caused by the separation, which afterwards forms a sheath for the young leg.[5]

Principal Divisions of the Crustacea.

The subjoined table is intended to give only a general outline of the Crustacean class, with the sub-classes, legions, and orders.

Of the thirteen orders enumerated two only (printed in italics in the table) are extinct, namely the *Trilobita* and *Eurypterida*. These two lost orders disappeared in the Carboniferous epoch.

Table of Classification of the Crustacea.

Class CRUSTACEA.

Sub-Class 1. *THORACIPODA* (or *Malacostraca*).

Legion I. Podophthalmia.

Order 1. Decapoda.
Sub-Order (*a*) Brachyura, *Crabs*.
(*b*) Anomoura, *Hermit-crabs*.
(*c*) Macroura, *Lobster*, *Prawn*.
,, 2. Stomapoda, *Squilla*, *Mysis*, *Diastylidæ*.

Legion II. Edriophthalmia.

,, 3. Isopoda, *Oniscus*, *Idotea*, *Sphæroma*.
,, 4. *Trilobita*, *Phacops*, *Asaphus*, *Calymene*, &c
,, 5. Amphipoda, *Talitrus*, *Gammarus*, &c.

Sub-Class 2. *GNATHOPODA* (or *Entomostraca*).

Legion III. Merostomata.

,, 6. Xiphosura, *Limulus*, *Bellinurus*, &c.
,, 7. *Eurypterida*, *Eurypterus*, *Pterygotus*.

Legion IV. Branchiopoda

,, 8. Phyllopoda, *Apus*, *Nebalia*, *Artemia*.
,, 9. Cladocera, *Daphnia*, *Lynceus*, &c.

Legion V. Lophyropoda.

,, 10. Ostracoda, *Cypris*, *Candona*, *Cythere*.
,, 11 Copepoda (*a*) Liberata: *Cyclops*, *Cetochilus*, *Diaptomus*.
(*b*) Parasita: *Lernanthropus*, *Caligus*, *Nicothoe*.

Legion VI. Anchoracephala.

,, 12. Rhizocephala, *Sacculina*, *Peltogaster*.
,, 13. Cirripedia, (*a*) *Balanidæ*, &c.
(*b*) *Lepadidæ*, &c.

If the old definition between the two great groups, the Malacostraca and the Entomostraca, be maintained, namely, that the former shall consist only of forms having

[1] Prof. Bell observes, "There is no doubt that exuviation in many of the higher forms takes place annually with great regularity until the growth is completed, which in many species is not the case before the animal is many years old. This is proved by the extent to which the size increases at each moult, compared with the difference between the young and the old animal; and it is evident that after the growth has reached its maximum, the crust ceases to be changed, from the fact which I have seen in several instances, as in the common crab, the lobster, and some others, where the carapace of the still living creature was the seat of barnacles so large, that several years must probably have been required for attaining their existing size" (*British Stalk-eyed Crustacea*, Introduction, xxxiv.). The young male of *Limulus*, according to Packard, does not attain to the period of puberty before it is four years old. Many Entomostraca infested with bell-animalcules depend on the moulting of their carapace as their only chance of surviving and escaping these prolific parasites.

[2] *Glimpses of Ocean Life* (1860).

[3] The frequency with which they exuviate, together with the durability of the cast-off integuments, explains the astonishing masses of exuviæ which Mr C. W. Peach observed annually off the coast of Cornwall, especially in the months of April and May; but he has seen quantities also in September. He could easily have filled several quart-measures with them (Darwin's *Balanidæ*, p. 157).

In connection with the exuviation of the Cirripedia Darwin mentions a most remarkable fact (*op. cit.* p. 15): "In regard to the female organs, the ovarian tubes and cæca inosculate together; there are no oviducts; the ova, connected together by membrane, and so forming the ovigerous lamellæ, become exposed *by the exuviations of the lining tunic* of the carapace or sack, and by the formation of a new tunic on the underside of these lamellæ,—a process unknown in other Crustaceans."

[4] It is a well-authenticated fact that the roll of thunder and the discharge of artillery over that part of the sea where lobsters resort will cause them to throw off their great claws. The same effect is also produced by the infliction of any sudden injury. If *Porcellana platycheles* be seized by the claw it immediately casts it off and beats a retreat without it.

[5] H. Goodsir, *Ann. and Mag. Nat. Hist.*, vol. xiii. p. 67.

more than twenty-one segments, the introduction of the Trilobita among these may be looked upon as inappropriate. If, however, we admit that the Trilobita had (as there seem good grounds for allowing) true special locomotory appendages other than gill-feet or jaws, as in the Malacostraca generally, then we submit that they are appropriately classed. The main characteristic of the Malacostraca seems to be, not so much the possession of twenty-one segments, an inheritance really common to the whole class, but the presence of the seven anterior (cephalic) appendages especially set apart for the senses and nutrition, with separate post-cephalic organs of locomotion;—whereas the peculiarity of the Entomostraca seems to be that the seven anterior (cephalic) organs are not specially set apart as organs of sense and nutrition, but are employed in nearly all the class as the chief locomotory organs, the posterior feet being branchial or ovarian lamellæ, or altogether wanting. The writer ventures to propose therefore, instead of

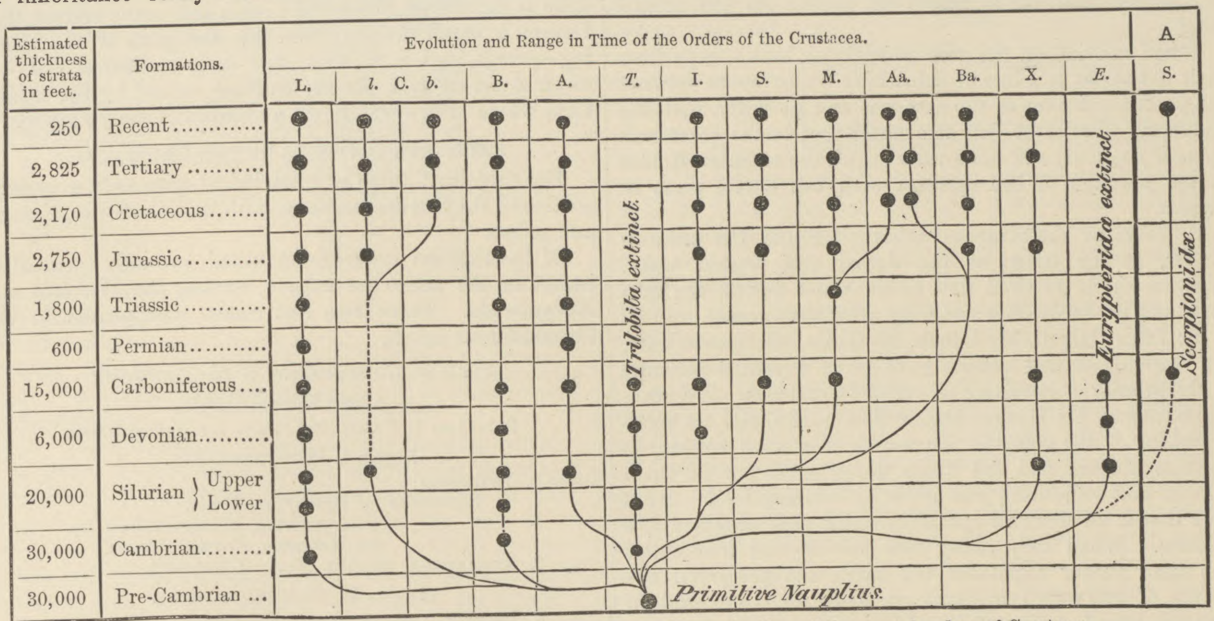


Fig. 64.—Diagram showing the probable evolution and actual range in time of the several orders of Crustacea.

Explanation.—The letters at the top of each column represent the several orders and sub-orders of Crustacea,—one family of the Arachnida, the *Scorpionidæ*, being placed beside the Eurypterida to show its range in time and probable derivation from the Crustacea. The vertical lines show the actual range in time, the black dots denote the strata in which remains of each order have been met with. The curved lines, uniting order to order, are intended to show the *probable* evolution of the class from a common great ancestor; but numerous as are the indications of affinities afforded by the Crustacea, the group is too ancient to be certainly traced back in time to a common parent; even the *lowest* Cambrian rocks have yielded evidence of two orders, namely, the Trilobita and Ostracoda, whilst the Middle Cambrian furnishes a Phyllopod Crustacean (*Hymenocaris*). As the branches of this genealogical tree of the Crustacea are not arranged in a circular manner, they cannot of course be made to show the affinities which each order presents to every other order or branch, any more than does the dried plant show the natural verticillate arrangement of its leaves and branches when pressed out flat upon the page of a *Hortus Siccus*.

L=the Lophyropoda. Of this legion, the order Ostracoda is well represented throughout the entire series, from the Cambrian to the Tertiary and also in the seas and fresh-waters of to-day.

C=the Cirripedia.—*l*=the Lepadidæ, or pedunculated Cirripedes, appear first in the Wenlock Limestone (U. Silurian); represented by a single form (*Turrilepas Wrightianus*, H. Woodw.). Numerous forms occur in the Secondary and Tertiary strata, and they are abundantly distributed throughout the warmer seas of the world. *b*=the Balanidæ, or sessile Cirripedes, are represented by a single form, the *Pyrgoma cretacea*, H. Woodw., in the Chalk, abundantly in the Tertiary rocks, and in recent deposits, and are distributed in the seas all over the world at the present day.

B=the Branchiopoda.—Of this division the order Phyllopoda appears in the Cambrian rocks, and is well represented in Silurian and Carboniferous strata; they are also met with in the Secondary and Tertiary formations, and living in fresh, brackish, and marine waters, widely distributed over the globe.

A=the Amphipoda.—This order has a single representative in the Upper Silurian, *Necrogammarus Salweyi*, H. Woodw.; it is represented by *Gampsonyx?* in the Coal, by *Prosoponiscus* in the Permian, and by several forms in the Secondary and Tertiary formations, and abundantly in recent freshwater and marine localities.

T=the *Trilobita*. This extinct order appears in the Cambrian, attains its maximum development in the Silurian, and terminates in the Carboniferous period.

I=the Isopoda.—This order is represented in the Devonian by a single species, *Præarcturus gigas*, H. Woodw., and by remains in the Carboniferous strata. Many species occur in the Secondary and Tertiary strata. It is largely represented to-day by land, freshwater, and marine types.

S=Stomapoda.—*Pygocephalus Huxleyi*, H. Woodw., from the Coal-measures, probably belongs to this division, True *Squillas* and *Mysis*-like Crustacea occur in the Jurassie rocks (Secondary). Forms of this order are abundant in our modern seas.

M=the Macrouran division of Decapoda. A single species, *Anthrapalæmon Grossartii* Salter, appears in the Coal-measures. This order is well represented from the Trias to the present day, and is now one of the prevalent types, occurring both in fresh and salt water.

Aa=the Anomoura, or irregular-tailed Decapoda. This sub-order embraces forms related both to the Crabs (*e.g. Dromia*, *Porcellana*, *Dorippe*) and to the Lobsters (*e.g. Pagurus*, *Galathea*, *Munida*). Their earliest appearance is in the Cretaceous period; there are numerous living forms, both terrestrial and marine.

Ba=the Brachyura.—The oldest known crab is the *Palæinachus longipes*, H. Woodw., from the Gt. Oolite. Crabs are well-represented from the Upper Secondary to the present day, when they attain their maximum within the warmer latitudes, being represented by land, freshwater, and marine forms.

X=the Xiphosura, or king-crabs. These are remarkable for their longevity; they appear first in the Upper Silurian (*Neolimulus falcatus*, H. Woodw.); again in the Coal-measures, next in the Oolite and Tertiaries, and living to-day in the Old and New Worlds.

E=*Eurypterida*.—This extinet order contains some of the largest known members of the Crustacean class (*e.g*, *Pterygotus anglicus*, Devonian). It ranges from the Upper Silurian to the Coal-measures. On morphological grounds there is good reason to conclude that the Eurypterida are the ancestors of the Scorpionidæ, to which they present the strongest affinity.

A=ARACHNIDA. S=Scorpionidæ.—The scorpions range from the Coal-measures, apparently unaltered, to the present day.

the terms Malacostraca[1] and Entomostraca,[2] which convey no idea of any structure or function common to either division to which they are applied, the adoption of the terms Thoracipoda[3] and Gnathopoda,[4] which embody the salient character in each sub-class.

The Trilobita are probably represented to-day by the Isopoda, to which doubtless they are closely related. There is reason to believe the members of the other extinct order, the *Eurypterida*, to have been the aquatic branchiferous ancestors of the terrestrial tracheated air-breathing *Scorpionidæ;* nevertheless they need not on that account be removed from their present position in the Crustacean

[1] From μαλακός, soft, and ὄστρακον, a shell,—a term not specially appropriate or applicable to crabs and lobsters.

[2] From ἔντομος, an insect, and ὄστρακον, a shell,—a name quite applicable to the Ostracoda, but not to all the sub-class.

[3] From θώραξ, the thorax (or middle body), and πούς, ποδός, a foot, in allusion to the prevalent use in the Malacostraca of the thoracic series of appendages as special organs of locomotion.

[4] From γνάθος, the jaw, the mouth, and πούς, ποδός, a foot, in allusion to the prevailing character in the Entomostraca, in which the head and *mouth-organs* are also mainly used in locomotion. We should of course have preferred to use the term *Cephalopoda* for this sub-class, had not that designation been already appropriated for the cuttle-fishes, &c.

class;[1] and the *Scorpionidæ* should of course still form a part of the class Arachnida, which may, however, be conveniently placed beside the Crustacea, as in the annexed diagram (fig. 64), in which their probable morphological and ancestral relationship is indicated.

Types of Existing Crustacea.

Sub-class 1. Thoracipoda (or *Malacostraca*).

I. Podophthalmia: (1.) Decapoda—(*a*) Brachyura.—Crabs are certainly the highest representatives of the Crustacean class, and in this ten-footed order[2] are included some of the most active and intelligent members of the community,—the "land-crabs," and "shore-crabs," and also the largest *living* representative of the class, the *Inachus Kempferi* from Japan.

Crabs furnish the best illustration among the Crustacea of that concentration of organs around a single nerve-centre, which Professor Dana aptly terms *cephalization.*

Instead of a long vermiform body composed of a large number of annuli, each having its own nerve-ganglion, we have in the crab one large cephalo-thoracic ganglion representing nearly the entire nerve force of the body, the supra-œsophageal ganglion only giving rise to the nerves of sense and volition. (See fig. 9, nerves of *Maia.*)

This highest cephalized type is exemplified by *Maia*, but as a matter of fact the triangular crabs, of which *Maia squinado* and *Inachus Kempferi* are examples, do not embrace, by any means, the liveliest and most intelligent of the order; on the contrary, we should decidedly award the highest place for intelligence to the quadrangular land and shore-crabs; indeed, it is amongst such genera as *Grapsus, Gelasimus, Ocypoda, Gecarcinus*, &c., that we find the most rapidly moving *terrestrial* forms of Crustacea. Most of the land-crabs retreat to burrows in the ground during the heat of the day, and issue forth at dusk to feed on the growing crops of sugar-cane, rice, or maize. The *Gecarcinus ruricola* (see *ante*, fig. 21) is peculiarly destructive to the young sugar-canes in the West Indies. In the highlands of the Deccan land-crabs are most abundant. *Gecarcini* are found at Mahableshwar at an elevation of 4500 feet above the sea. These land-crabs probably do not visit the sea at all, as do the Jamaica land-crabs, but deposit their eggs, when near the time of hatching, in the freshwater streams, the banks of which they are known to frequent. Many of the land-crabs have the chelate limbs largely developed, usually more strongly so in the males, *e.g.*, the male of *Macrophthalmus Latreillii*; in others one claw only is very disproportionately enlarged, as in the males of the "calling-crab" (*Gelasimus*), which are said in running to carry this claw elevated as if beckoning with it. Fritz Müller says, however, that the species common in Brazil (a small *Gelasimus* with one claw *very large*) always holds it

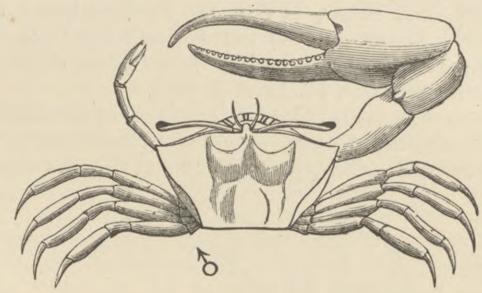


Fig. 65.—The "Calling-Crab" (*Gelasimus*), ♂ a land-crab common in the cassava-fields, Brazil.

closely pressed against its body. Vast numbers of land-crabs are met with on the sea-shore and among rocks along the coast, especially in the warmer temperate and sub-tropical regions of the earth. Of the genus *Thelphusa* one freshwater species (*T. fluviatilis*) is a native of the rivers of southern Europe. It is eaten by Catholics during Lent, and hence called "Lenten crab." This crab is also common to the rivers of India.

Although some land-crabs are certainly vegetarians in diet, the class, as a whole, are carrion feeders, greedily devouring animal matter even in a putrescent state. The *Portunidæ* and *Carcinidæ* perform the duties of sanitary police around our coasts between tide-marks, being assisted by swarms of "sand-hoppers" (*Talitrus locusta*); whilst below low-water mark the prawns, *Maias*, great crabs, and lobsters share the task. Many sea-side resorts would be extremely unwholesome were it not for the labours of these useful but unpaid scavengers.

The swimming-crabs are mostly predaceous; forms like *Portunus pelagicus* and *Polybius Henslowii* (fig. 66) have exceedingly thin shells, and all the feet, save the great chelate claws, are modified into oars. They are thus enabled to live and hunt at their ease, often hundreds of miles from land. The writer has seen Henslow's swimming-crab in the middle of the Bay of Biscay far out of sight of land. Crouch, the Cornish naturalist, states that they fasten upon pilchards and mackerel with their knife-like claws, and never relax their hold until the terrified victim floats exhausted on the surface.

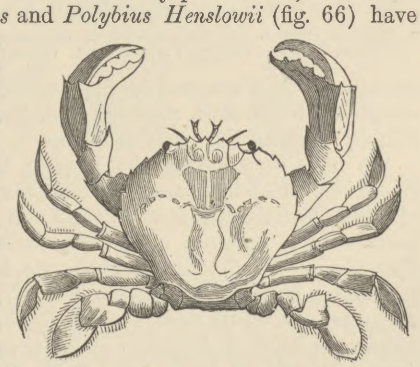


Fig. 66.—Henslow's Swimming-crab, *Polybius Henslowii*, Leach, coast of Cornwall.

Two genera of Tertiary Land-crabs have been described from English localities (*Goniocypoda*[3] and *Litoricola*).[4] *Macrophthalmus* occurs fossil in China, where it is prized as a valuable *materies medica.*[5] *Ranina*, "the frog-crab" of the Indian Ocean and Japan, occurs in Tertiary rocks[6] in Bunde and Ebenda, Germany, in San Stefano, Italy, and

[1] In a paper on the structure of the Xiphosura and their relationship with the Eurypterida (*Quart. Journ. Geol. Soc.*, 1866, vol. xxiii. p. 35), the writer first suggested the probable genealogico-morphological relationship between *Pterygotus* and *Scorpio*; and in a subsequent communication (*op. cit.* 1871, p. 46) he combated the proposal of Dr Anton Dohrn to remove the Trilobita, Eurypterida, and Xiphosura from the Crustacea, and to combine them with *Scorpio* as a new class beside the Crustacea; he also pointed out wherein the evidence relied upon by Dohrn for establishing such an order fails. The classification of the *Eurypterida* and *Xiphosura* proposed in his monograph (*Pal. Soc. Mon. Merostomata*, Pt. i.-iv., 1866-72) has been adopted by Professors Owen and Huxley both, and has received the sanction of many eminent carcinologists. The writer has given his views as to the close affinity between the extinct Trilobita and the modern Isopoda in *Brit. Assoc. Reports, Edinb.*, 1871, and *Geol. Mag.* 1871, vol. viii. p. 289, pl. 8.

[2] The crabs belong to the legion Podophthalmia, all the members of which are distinguished by having their compound eyes placed on movable eye-stalks (hence called "stalk-eyed Crustacea"). They also have the gills covered by the carapace, forming, in fact, a more or less completely enclosed branchial chamber. Only one other Crustacean viz., *Tanais* (fig. 38), an Isopod, has such an arrangement—in *Tanais* also the eyes are pedunculated. In *Nebalia* (2 in fig. 57), a Phyllopod, the eye is pedunculated, but in these instances the peduncle is not articulated. In the Trilobita several species occur with compound pedunculated eyes, but the eye-stalk has no articulus.

[3] *Goniocypoda Edwardsii*, H. Woodw., L. Eocene, High Cliff, Hampshire *Geol. Mag.*, 1867, vol. iv. pl. 21. fig. 1, p. 529.

[4] *Litoricola glabra*, H. Woodw., and *L. dentata*, H. Woodw., L. Eocene, Portsmouth, *Quart. Journ. Geol. Soc.*, vol. xxix. pl. 2, p. 29.

[5] *Notes on Chinese Materia Medica* by D. Hanbury, F.L.S., *Pharm. Journ.* 1862, p. 43.

[6] See Woodward and Salter's Chart of the Fossil Crustacea, engraved by J. W. Lowry; Stanfords, Charing Cross, 1865.

in Malta. Rumphius says, "It loves to climb upon the roofs of houses."[1]

More than fifty genera of fossil Crustacea, referable to the Decapoda-Brachyura, have been described by Milne-Edwards, Bell, Reuss, M'Coy, H. Woodward, and others The oldest known crab is the *Palæinachus longipes*, H. Woodw., from the forest marble, Wilts (*Quart. Journ. Geol. Soc.*, 1866, vol. xxii. Pl. xxiv. p. 493).

I. Podophthalmia: (1.) Decapoda—(*b.*) Anomoura.—The irregular-tailed or Anomourous Crustaceans, of which the hermit-crab is a type (figs. 20 and 67), are excellent

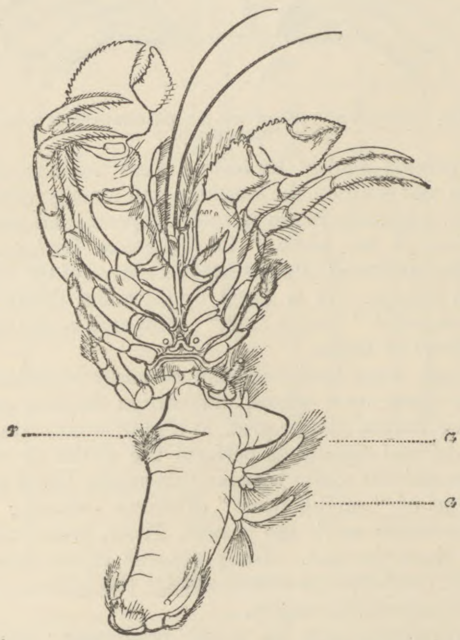


Fig. 67.—Hermit-Crab removed from its shell (see *ante*, fig. 20).
r, hardened ridge which bears against the columella of snail-shell; *a*, *a*, the appendages to which the eggs are attached. (Morse)

examples both of arrested development and retrograde metamorphosis in the adult, resulting from disuse and consequent atrophy of particular parts or organs.

We have seen among the Isopoda the females of the *Bopyridæ*, which live parasitic within the branchial chamber of other Crustaceans, or under their abdomen, or within the parietes of a *Balanus*, or actually within the body of a *Porcellana*. In the Rhizocephala we have seen the free-swimming pupa become attached to the soft body of the *Pagurus*, cast off its shell, lose all its limbs, and appear as a sausage-like, sack-shaped, or discoidal excrescence, without even a mouth, its body, filled with ova, attached by its antennæ, which are modified into roots, that anchor it and at the same time bring it ready prepared nourishment from the juices of its hosts (see figs. 82 and 83). After such extreme retrogression, the depauperization of certain parts and organs observable in the Anomoura is easily to be understood and admitted.

If we bring together for study a series of Anomourous Crustacea, we shall be at once able *superficially* to divide them into two sections, the *Macrourous* and the *Brachyurous Anomoura*.

(A.) *Irregular* Brachyura.	(B.) *Irregular* Macroura.
1. *Lithodes.*	1. *Galathea.*
2. *Porcellana* (fig. 68.)	2. *Munida.*
3. *Dromia.*	3. *Paguri* (fig. 67.)
4. *Dorippe.*	4. *Birgus.*
5. *Homola.*	

We have also burrowing forms which obviously are near to these, although not actually classed with them, viz.,

1. *Ranina.*	1. *Callianassa.*
2. *Corystes.*	2. *Gebia.*
	3. *Axius.*

In both these sections of the Anomoura we find the same peculiarity, namely, that the fifth pair of (thoracic) legs, and sometimes indeed the fourth and fifth hinder pairs, are not formed for walking, but are minute and rudimentary, and are placed *above* the level of the other legs.

In *Porcellana* and *Lithodes*, in *Galathea* and *Munida*, the posterior legs are simply rudimentary. In *Dorippe* and *Dromia*, in *Pagurus* and *Birgus*, though still disproportionately small, they are modified into organs for holding on with. This rudimentary condition of the posterior thoracic feet in the Anomoura at once recalls the last larval stages of nearly all the Malacostraca,[2] in which the hinder thoracic somites are not yet developed, or if so, are either destitute of appendages, or have only rudimentary ones.

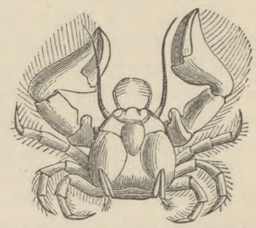


Fig. 68.—*Porcellana platycheles*, Penn. sp. British. Habitat under stones at low-water.

The chelate form of the two posterior pairs of feet in *Dromia* and *Dorippe*, in *Homola* and *Birgus*, being a variable characteristic, and not present in all Anomoura, is doubtless developed as an *individual* specific modification, like the chelate penultimate feet in *Brachyscelus* and the ante-penultimate pair in *Phronima*.[3]

Some Anomoura have chelate terminations to a pair of their rudimentary feet, others have both pairs simple.[4] This is at once elucidated when we inquire into their economy. *Dromia* does not carry about a turbinated shell like *Pagurus*, but clothes itself with the *skin* of its victim, a "sea-lemon" (*Doris*) for example, or encourages a parasitic sponge of showy colour to grow upon its back, holding it in its place with its two hind pairs of rudimentary feet, just as the other true hermits hold their shells on over their soft-skinned bodies (Gosse).

Professor Verrill has described a *Dorippe* (*D. facchino*), which always carries an *Actinia* (the *Cancrisocia expansa*, St.) upon its back. Like most other cases of *commensalism* this friendly association of the crab and sea-anemone was begun long ago and has been regularly adhered to. When young the *Dorippe* carries a small shell (? the half of a bivalve), which it holds in position by means of its two hind pairs of legs. The *Actinia* fixes itself when young to the shell, and afterwards by its growth completely conceals the carapace of the crab, replacing the shell which is, no

[1] (Fritz Muller, *Für Darwin*, p. 30). This statement of the old Dutch naturalist seems most extraordinary, and needs further investigation. All the feet in *Ranina* seem adapted for digging, and an allied but much smaller form (*Raninoides*) from Trinidad, a truly marine species, is a most expert burrower into sand or mud, going down tail foremost. According to Milne-Edwards, in *Ranina* the ordinary entrant orifice to the branchial cavity is altogether wanting, and the entrance is by a canal which opens *beneath* the abdomen. Such an arrangement seems rather to favour the notion of its fossorial habits.

[2] In *Palæmon* and *Penæus* (Macroura), in *Dulichia*, *Caprella*, *Ligia*, and *Asellus* (Isopoda), in *Lestrigonus* (Amphipoda), and even in the Brachyura where the young apparently undergo little transformation when compared with the less cephalized forms, the thoracic somites are developed last, and then from before backwards. (See Spence Bate on the Development of Decapod Crustacea, 1857, *Phil. Trans.* 1858, p. 595.)

[3] In *Cenibota Diogenes*, one of the land-hermits, the penultimate pair of feet are furnished with curious rasp-like surfaces to their extremities, to enable it to hold on to the smooth inner surface of the spiral shell it has chosen for a habitation.

[4] In the *Hyperiæ* the youngest larvæ cannot swim; they are helpless little animals which cling firmly by their chelate feet to the swimming laminæ of the *Medusæ* in the gill-cavity of which they live when adult; the adults lose the prehensile character of the feet and acquire the power of swimming.

doubt, after a time either disintegrated or abandoned when the *Dorippe* moults. A *Sagartia*, associated with a hermit-crab on our own coasts, is said entirely to dissolve away the *Buccinum* in which the *Pagurus* is lodged, and to supply its place, as in the case of *Dorippe*, with its expanded foot.

Several specimens of a small species of *Pagurus*, common on the French coast, have been brought to the writer, each crab tenanted in what appeared to be the shell of a small *Buccinum* or *Nassa;* but the whole was so completely encrusted by a sponge as to leave no part visible externally. On cutting one open vertically the spiral form of the interior cavity of the shell was very distinctly seen, but the shell itself had been entirely dissolved away by the sponge.[1]

A *Zoanthus* has been described by Duben and Koren under the name of *Mammalifera incrustata*, which is commonly found parasitic on shells that are tenanted by a species of *Pagurus*. In all cases the shell is destroyed after a while, *not by the hermit-crab*, but by some process of disintegration or absorption, the diffused basal crust of the Zoophyte forming a perfect cast of it, and affording shelter to the crab. This form occurs in Shetland and in the North of England, as well as in Norway, and is regarded by Mr Hincks as distinct from *Zoanthus Couchii*, Gosse (Rev. T. Hincks, *Ann. and Mag. Nat. Hist.* 1862, p. 304).

The *Adamsia palliata* always selects shells tenanted by *Pagurus Prideauxii*, but instead of adhering to the spire the "cloak-anemone" fixes itself to the smooth inner lip of the shell, so that when the hermit is feeding, the mouth of the anemone is just below that of the crab, and ready to receive any fragment he may let fall. When the *Adamsia* is very young, less than half-an-inch in diameter, its outline is circular; but as it grows older it expands laterally, forming two lobes, which creep along the mouth of the shell, until they meet and coalesce on its outer lip. The base of the cloak-anemone is then perforated, and through this opening the hermit puts out or retracts his head and legs.[2]

In all the Anomoura the abdomen is more or less modified; for instance, in the Brachyurous type, it is not closely bent under the body, as in ordinary crabs, some *Porcellanæ* (fig. 68) carrying it extended straight out; whilst in the long-tailed forms, like *Galathea*, the epimera are shorter, and the segments are less arched than in the lobster. The caudal plates are also more rudimentary. In *Pagurus* (fig. 67), the abdomen is naked, only a mere trace of the shelly plates remaining. In *Birgus latro* the sternal portion only of the abdominal somites remains.

If we turn for an instant to the *Thalassinidæ*, a family of burrowing Macroura, we find the hard and shelly epimeral pieces of the body-segments are not properly developed, and the lobes of the tail are in like manner rudimentary; the integument of the body is extremely thin and soft (approaching that of the hermit-crabs, which like themselves live concealed in various foreign substances living and dead, *e.g.*, shells, sponges, *Actiniæ*, &c.).[3]

There can be no doubt that both in the case of the true hermit-crabs, and in that of the burrowing Crustacea, the

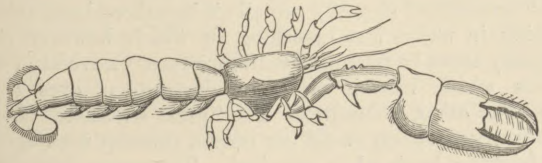


FIG. 69.—*Callianassa subterranea*, Leach, a burrowing Crustacean; coast of Devon (other species are found fossil in the Chalk, Greensand, London Clay, &c.).

non-development of the *hard* calcareous covering to the abdomen (in *Callianassa* extending to the whole body except the legs and chelæ) is due to the same cause, viz., disuse of the abdomen and caudal fin for natation, and to their constant habit of living in concealment.

In the case of *Birgus latro*, when quite young it probably conceals itself in some shell, but as it grows to such a large size and becomes so enormously fat, from feeding upon the cocoa-nut, it must abandon its early disguise and conceal itself within a burrow instead. The writer has received a small hermit-crab very like *Birgus*, the abdomen of which was concealed in a sponge.

If then the Anomoura be the descendants of certain Crustacea in which an arrested stage of development in the young has become a persistent character in the adult, or in which organs atrophied by disuse have at last come to be suppressed or greatly modified, the conclusion seems obvious that we are dealing not with a distinct sub-order equivalent to the Brachyura or the Macrura, but with a group composed of various irregular forms at present placed intermediate to, but originally belonging to *both* these divisions.

Forms allied to *Homola* and *Dromia*—*Homolopsis* and *Dromilites*—occur fossil, the former in the Gault and the latter in the London Clay (in fig. 70); no other Anomourous forms have been met with, save some legs and chelæ in the Chalk, which have been attributed to a *Pagurus*.

Remains of *Callianassa* are very abundant in the Cretaceous and Tertiary rocks of Europe, and have been found fossil even as far off as Japan. It is always the hands which are preserved, the body being usually too delicate for fossilization.

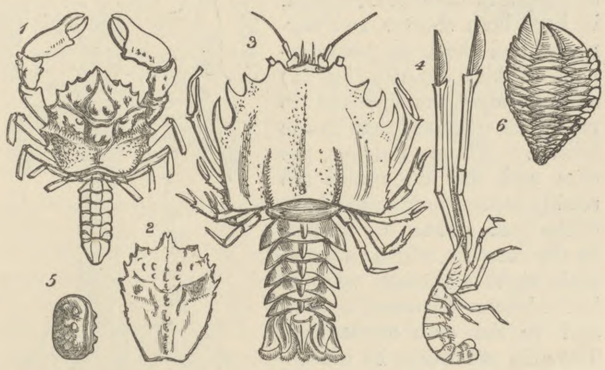


Fig. 70.[4]—1, *Dromilites Lamarckii*, Desm.; London Clay, Sheppey. 2, *Palæocorystes Stokesii*, Gault; Folkestone. 3, *Eryon arctiformis*, Schl.; Lithographic stone, Solenhofen. 4, *Mecocheirus longimanus*, Schl.; Lithographic stone, Solenhofen. 5, *Cypridea tuberculata*, Sby.; Weald, Sussex. 6, *Loricula pulchella*, Sby.; L. Chalk, Sussex.

I. PODOPHTHALMIA: (1.) DECAPODA—(*c.*) MACROURA.—The common lobster and prawn are excellent examples of the Macroura. In this truly aquatic type the abdomen is no longer rudimentary, as in the crabs, but is developed into a powerful organ for leaping and swimming. The body-segments are of nearly equal growth, and being compressed at the sides, or cylindrical in form, they present a well-marked contrast to the crabs, or Brachyura, in which the segments are expanded laterally. The abdomen is terminated by a broad swimming tail. The Macroura are numerically very abundant in both marine and fresh water.

The lobster prefers a rocky coast, and being somewhat of a *gourmand* in his tastes is tempted by the fisherman on our shores to such good purpose, that as many as 25,000 live lobsters are often delivered at Billingsgate in a day. If only as many are eaten in the whole of England as in London, this would be at the rate of 50,000 per day, or

[1] They are found tenanting shells covered by *Cellepora edax* and by *Hydractinia*. The hermit-crabs are known to break out the spiral columella of the shell they inhabit to give themselves more room.

[2] Gosse, *Glimpses of Ocean Life;* see also Professor Verrill's article, *American Naturalist*, vol. iii.

[3] We may compare the differences of their tests to that which exists between a lady's white and delicate hand, encased from infancy in a kid glove, and the hand of a primitive savage who uses his digits constantly for delving in the ground for roots. In the one the covering membrane is thin and soft, in the other hard and horny. One might even go further and imagine that, by continued disuse, the nails would be no longer developed; certainly they have in civilized life become less powerful as offensive weapons, and the toe nails on the feet have really in most persons commenced to become atrophied.

[4] From Professor Owen's *Palæontology*, p. 50, fig. 10.

18,250,000 annually. March to August is the period of greatest catch.[1]

The river cray-fish, *Astacus fluviatilis* (fig. 25), also common to the rivers of Europe, is largely caught, and when fresh boiled is not to be despised. It is largely imported into London, and is used by the *chefs* at the West End to garnish dishes. The writer with a friend caught as many as 900 cray-fish in a single evening from 8 till 12 (with a series of simple scale-like nets baited with liver), along the bank of the Thames and Severn Canal, Gloucestershire. The Murray river cray-fish from Australia (*Potamobius serratus*) is as large as a fine sea-lobster, and has its segments ornamented with spines, reminding one of the spiny lobster[2] (*Enoploclytia sussexiensis*) from the chalk of Sussex and Kent.[3]

More than fifty genera of fossil Macroura have been met with and described; the earliest known is the *Anthrapalæmon Grossartii* from the Lower Carboniferous series near Glasgow. Similar forms have been obtained from the Coal-measures in England; from Illinois, U.S.; from Bohemia, &c.

I. PODOPHTHALMIA: (2.) STOMAPODA.—All the members embraced within the three divisions of the preceding order (Decapoda) were cryptobranchiate, in this order they are nudibranchiate, *i.e.*, the gills are composed of plates or simple filaments attached to the feet, whilst the carapace, so largely developed in the order Decapoda, is here both shorter and narrower, and the body less compact. Taking *Squilla* (fig. 71) as an example, the segments are much less coalesced than in the lobster. Those bearing the eyes and the antennules are readily separable from the front of the head, and are not covered by the carapace, which only conceals eight segments, whereas in the lobster it covers fourteen, and in the crab twenty-one. The gills are borne by the abdominal swimming feet, free and uncovered. The first pair of thoracic limbs are developed into a pair of large and formidable claws, the terminal joint of which bears a row of long, sharp, and recurved teeth; these double back upon the edge of the penultimate joint which has a groove to receive them, like a pocket-comb.

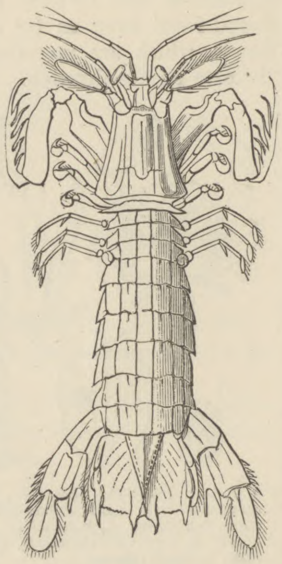


Fig. 71.—*Squilla mantis*, Rondel.; south coast of England and Mediterranean.

In *Mysis*, "the opossum shrimp," another member of this order, the two posterior pairs of feet only are branchiferous; all the feet are biramous and flagellate; in the female the hinder feet are modified into broad plates which, uniting beneath the body, form a pouch or *marsupium* in which the eggs are protected and the young pass through their infancy.[4]

These opossum-shrimps, which are pelagic in their habits, are frequently met with in countless myriads towards the surface of the Greenland Sea, and, though small, they form the chief part of the food of the common whale (*Balæna mysticetus*).[5]

Some forms of *Erichthys* are included in this division; these, like *Mysis*, are also pelagic, and occur abundantly on the surface of the Indian and Atlantic Oceans, where, together with the larvæ of Cirripedes and many other oceanic cosmopolites, they may be taken with the towing net in abundance.

Numerous specimens of true *Squilla* (*Sculda pennata*, Münst) and of a *Mysis*-like Crustacean have been found fossil in the Solenhofen limestone, of Oolitic age, in Bavaria. With the Stomapoda are also placed a group of very anomalous and larval-looking Crustacea (the *Diastylidæ*) originally noticed in 1843 by Mr Harry Goodsir, who obtained them from the Firth of Forth. They closely resemble Copepoda in aspect, and might readily be confounded with the larval stages of some Decapod. They have, however, been found with their eggs borne by the female in an incubatory pouch beneath the thorax, as in *Mysis*.

The branchiæ are situated on each side of the thorax immediately above the insertion of the legs, and approach in their comb-like appearance to those of the higher Crustacea.

Three genera have been established for these singular forms, namely, *Cuma*, *Alauna*, *Bodotria* (see fig. 36).

II. EDRIOPHTHALMIA: (3.) ISOPODA.—From the stalk-eyed Podophthalmia we pass now to the sessile-eyed Edriophthalmia, in which the eyes with one exception are fixed immovably on the surface of the head. As in the higher forms, the eyes are compound, consisting in the young of some ten or twelve lenses only, but in the adult of as many as sixty to eighty. In nearly all, the body is distinctly divisible into three parts—the head usually very small, the seven thoracic segments well and evenly developed, the abdominal somites more or less coalesced. The general conformity in size and function of the thoracic somites and their seven pairs of legs characterizes the majority of the Isopoda. These legs are nearly uniform, and are fitted either for walking or for swimming, or as powerful hook-like organs to enable them to adhere to the fishes on which they are parasitic. The branchiæ in this order are transferred from the thoracic legs to the abdominal appendages, which are converted into special organs of respiration.

One group of Isopods, the *Oniscidæ* (forming Spence Bate's and Westwood's family Ærospirantia), familiar in our gardens under the names of "woodlouse," "sow-bug," and "armadillo" (fig. 22), are all air-breathers, incapable of existing in water, but breathing air which, however, it is necessary must be saturated with moisture. Several of the species which inhabit caves are destitute of eyes (*e.g.*, *Titanethes albus*, Schrodte). The "great sea-slater" (*Ligia oceanica*) is common on all our coasts, running with agility and feigning death when attacked. The genus *Armadillo*, found commonly in our gardens and woods, and so called from the perfect way in which the segments roll together, forcibly reminds one of "the great Barr Trilobite" (*Illænus Barriensis*), from the Silurian of Staffordshire (7 in fig. 73).

A very interesting little Isopod (presented to the British Museum by Dr Milligan of Tasmania), from Flinders Island, Bass's Straits, and named in MS. by

[1] Lobsters are sent alive to the London market, packed in damp sea-weed, moss, or heather, from Stornoway in the Island of Lewis, from Ireland, Scotland, the Orkneys, the south coast, and Channel Islands, and from Norway. Fishermen and salesmen are said to know the south coast, Cornish, Scotch, Irish, or Norwegian lobsters at sight, just as cattle salesmen know a "Hereford" or "Devon," a "Scotch" or "Irish" beast. The largest common lobsters weigh from 8 to 12 tb. But the great lobster of the American coast (largely imported in tins into Europe) weighs more than twice as much.

[2] Dixon's *Geology of Sussex*, tab. 38, figs. 6, 7.

[3] For the numerous species of *Palæmonidæ* belonging to this division, we must refer the reader to Bell's *British Stalk-eyed Crustacea*, to Dana's magnificent volumes and atlas on the Crustacea found during the United States exploring expedition, and to De Haan's *Fauna Japonica*, and Milne-Edwards's *Hist. Nat. des Crustacées*.

[4] An allied species to *Mysis*, *Thysanopoda* (obtained in myriads by Couch on the Cornish coast from the stomachs of mackerel), carries its eggs, as does *Cyclops quadricornis*, in two bag-like ovaries depending from the posterior thoracic somite (Bell's *Brit. Stalk-eyed Crust.*)

[5] Otho Fabricius, *Fauna Groenlandica*, p. 245.

Mr Adam White *Ceratocephalus Grayanus*, offers many points of analogy with the extinct Trilobites. The fragile mode of articulation of its walking legs, and their entire

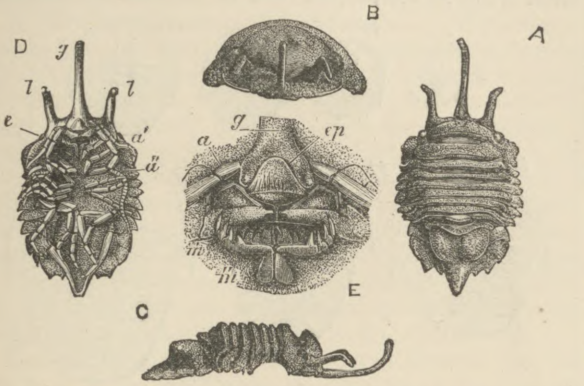


FIG. 72.—*Ceratocephalus Grayanus;* Flinders Island, Bass's Straits. A, the dorsal aspect. B, front view of the head showing the curvature of the three spines. C, side view. D, ventral aspect: *g*, the glabellal spine; *l*, *l*, the two lateral or genal spines of the head; *e*, the eye; *a*,' the antennule; *a''*, the antennæ the legs are seen folded up beneath the body. E, the mouth enlarged, showing *ep*, the epistoma or upper lip plate, *m'*, the mandibles, *m''*, the pectinated maxilla, *a*, the antenna; the epistoma is set in the base of the glabellal spine *g*.

concealment beneath the body-segments, are very suggestive. This Isopod is near to the *Sphæromidæ*, but will form a distinct family, as the antennæ are inserted beneath and within the margin of the head-shield; apparently it does not roll itself into a ball.

The *Sphæromidæ* are very littoral in their habits; they range from the equatorial latitudes to the colder temperate zones, but are not found in Polar regions. They are vegetable feeders, and some (like *Limnoria*) are guilty of destroying timber. When molested or alarmed they roll themselves up into a ball. The *Sphæromidæ* present many points of analogy, if not of affinity, with the extinct Trilobites.

In this order we find the *Limnoria terebrans* (or the "gribble," as it is called by the fishermen). It is one of the most destructive creatures, attacking all woodwork below tidemarks; the only wood which it cannot destroy is teak. Although its ravages had gone on for ages, it was only made known to the scientific world and described by Dr Leach in 1811.

In the aberrant genus *Tanais* (fig. 38) the first pair of thoracic legs are converted into chelæ, and the head-shield is covered by a carapace, abundantly traversed by currents of blood, beneath which a stream of water passes, maintained as in the zoëæ and adult Decapoda by a flabelliform appendage of the second pair of maxillæ, which is wanting in all other Edriophthalmia. The abdominal feet, which in other Isopoda act as respiratory organs, are simple natatory feet in *Tanais*. These characters, together with the pedunculated eyes and the great chelate hands, give to *Tanais* a very decapod-like aspect (see fig. 38).

The *Idoteidæ* contain representatives of some of the largest known Isopoda, some of which are above 4 inches in length.

The *Ægidæ*[1] and *Cymothoidæ* have all the feet furnished with a robust finger, sharp at the tip, for seizing and holding on to fishes upon which they are parasitic. Another family, the *Bopyridæ* (fig. 39) are parasitic chiefly on members of their own class, frequently occupying the branchial chamber of the common prawn, and distorting the carapace on one side. A fossil *Bopyrus* is observed lying in the branchial cavity of a crab (*Palæocorystes*) from the Gault and Greensand.[2] We have already referred to these and other parasitic forms in the earlier part of this article.

Isopoda are met with as far back as the Old Red Sandstone, where remains of a gigantic species allied to *Arcturus* have been discovered; others occur in the Carboniferous and Oolitic periods. The Purbeck beds of Swanage, Dorset, also yield abundance of a freshwater form, the *Archæoniscus Brodiei;* species of *Oniscus* and *Sphæroma* are found fossil in the Cretaceous, the Eocene, and the Miocene of Europe.

II. EDRIOPHTHALMIA: (4.) TRILOBITA.—So long ago as 1821 Audouin placed the Trilobites with the Isopoda, whilst Macleay assigned them a distinct order between the Isopoda and the Phyllopoda. Later researches by Milne-Edwards

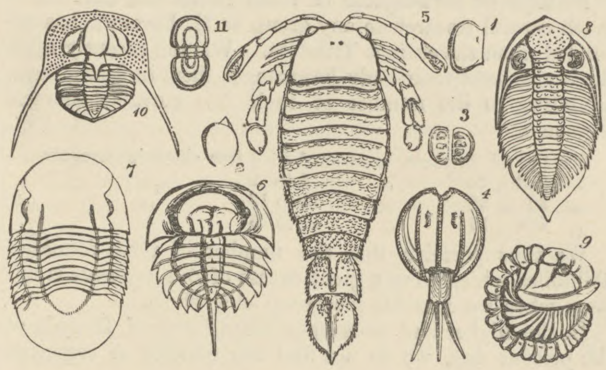


FIG. 73.—1, *Leperditia Baltica*, Wahl.; U. Silurian, Gothland. 2, *Entomoconchus Scouleri*, M.C.; Carbonifs. L. Ireland. 3, *Beyrichia complicata*, Salter; Lr. Silurian, Wales. 4, *Dithyrocaris Scouleri*, M'Coy; Carbonifs. L. Ireland. 5, *Pterygotus anglicus*, Ag.; Old Red, Forfarshire. 6, *Prestwichia rotundata*, H. Woodw.; Carbonifs., Coalbrookdale. 7, *Illænus Davisii*, Salter; L. Silurian, Bala. 8, *Phacops caudatus*, Brunn.; U. Silurian, Dudley. 9, *Calymene Blumenbachii*, Br.; U. Silurian, Dudley. 10, *Trinucleus ornatus*, Sternb.; L. Silurian, Britain. 11, *Agnostus trinodus*, Salter; Lr. Silurian, Britain.

and others have caused the Trilobita to be referred to the Entomostraca, on account of the very variable number of body-rings observed in the several genera (from six to twenty-six) evidencing a much lower type of structure than the Isopoda, in which the thorax is composed of seven free and movable segments with a head-shield and anchylosed caudal somites. Moreover, until the discovery of presumed ambulatory appendages in an *Asaphus* from the Trenton Limestone in 1870,[3] the only appendage previously observed was the hypostome or lip-plate. There seems, however, no good reason to urge against the conclusion that the Trilobita were an earlier and more generalized type of Crustacea, from which the later and more specialized Isopoda have arisen,—a view which the writer is glad to say he shares with the distinguished carcinologists, Professor Dana[4] in America, and Mr C. Spence Bate in England, although at present more evidence is needed as to the nature of the locomotory appendages in this extinct group. If we range the characters of Trilobita and Isopoda side by

[1] One species, *Eurydice pulchra*, common in the Dee, Cheshire, actually attacks bathers. "If you remain a moment still in the water dozens will fasten on you and nip most unpleasantly. I have had to jump into the water again after coming out from bathing, and splash violently to get rid of the hosts that had stuck to me while clinging to the side of the boat preparatory to getting in. They continue to bite after you are out of the water."—Extract of letter from Mr Walker to Mr C. Spence Bate.

[2] Mr James Carter, F.G.S., lately showed the writer a *Palæocorystes* from the Cambridge Greensand, having a *Bopyrus* lodged in each of its branchial chambers.

[3] Billings, *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 479.

[4] Professor Dana writes, "The Trilobita probably belong with this second type" (the Edriophthalmia, or *Tetradecapoda*, as Dana names them) "rather than with the Entomostraca. Yet they show an aberrant character in two important points. First, the segments of the body are multiplied much beyond the normal number, as in the Phyllopoda among the Entomostraca; and Agassiz has remarked upon this as evidence of that larval analogy which characterizes in many cases the earlier forms of animal life. In the second place, the size of the body far transcends the ordinary Isopodan limit. This might be considered a mark of superiority; but it is more probably the reverse. It is an enlargement beyond the normal and most effective size, due to the same principle of vegetative growth which accords with the (occasional) inordinate multiplication of the segments in the body" (*American Journ. Science*, July, 1856, vol. xxii. p. 11).

side, we shall find there are sufficiently good grounds for placing them in the Edriophthalmia together [1]

Trilobita (Fossil, extinct).	*Isopoda* (Fossil and living).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
2. No ocelli visible.	2. No ocelli visible.
3. (Appendages partly oral, partly ambulatory, arranged in pairs).	3. Appendages partly oral, partly ambulatory, arranged in pairs.
4. Thoracic segments *variable in number, from* 6 *even to* 26, free and movable, animal sometimes rolling in a ball.	4. Thoracic segments *usually seven*, free and movable, animal sometimes rolling in a ball.
5. Abdominal somites coalesced, forming a broad caudal shield (bearing the branchiæ beneath?).	5. Abdominal somites coalesced, forming a broad caudal shield, bearing the branchiæ beneath.
6. Lip-plate, *well-developed*.	6. Lip-plate, *small*.

Perhaps no investigator of fossil forms has devoted so much careful research to any group as M. Barrande has expended upon the extinct Trilobita. Writing recently upon the divisions of their body he arranges them in four groups, according to the number of their free movable thoracic segments.

The 1st,	of 2 genera,	has from	1 to 4	free thoracic segments.
,, 2nd	,, 24	,,	5 to 9	,,
,, 3d	,, 32	,,	10 to 13	,,
,, 4th	,, 16	,,	14 to 26	,,

We thus perceive that the number of those forms of Trilobites which have a great excess of *free segments* is not large when we consider the group as a whole.

In the higher and more specialized forms of Isopoda of the present day, we do not find the number of segments

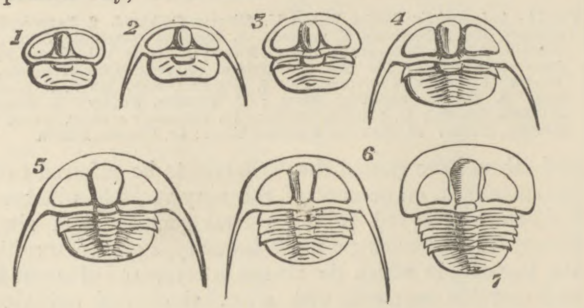


FIG. 74.—*Trinucleus ornatus*, Sternb. sp. (copied from Barrande's *Système Silurien du Centre de la Bohême*, Prague, 1852, 4to, plate 30). Specimens arranged in series according to their supposed age. (All the stages figured by Barrande are not given here.)
1. Young individual, destitute of thoracic segments, composed of head-shield and pygidium only.
2. Another of the same stage, in which the genal or cheek spines are developed.
3. Individual with one thoracic segment developed, but without the genal spines.
4. Another of the same stage, with the genal spines.
5. Individual with two thoracic segments, and with the genal spines present.
6. Individual with three thoracic segments, and possessing the genal spines.
7. Individual with five thoracic segments, but without genal spines.

absolutely adhered to without any variations; on the contrary, we constantly meet with individuals in which more or fewer segments are welded together, so as to conceal the normal number of seven thoracic somites between the head and the abdomen. Such being the case, we cannot be surprised to find considerable variation in a group like the Trilobita, which, if they really are the remote ancestors of the recent Isopoda, must, according to the views suggested above, be the prototypes of the larvæ rather than of the adult stage of the living Isopoda.[2]

In his researches among the Trilobites of Bohemia M. Barrande has discovered forms which, there is every reason to believe, exhibit (as he has so admirably shown in his great work) the gradual development of the Trilobite from the earliest form on quitting the egg to the adult. We give seven of the earliest stages of *Trinucleus ornatus* and seven of *Sao hirsuta*, copied from M. Barrande's monograph.

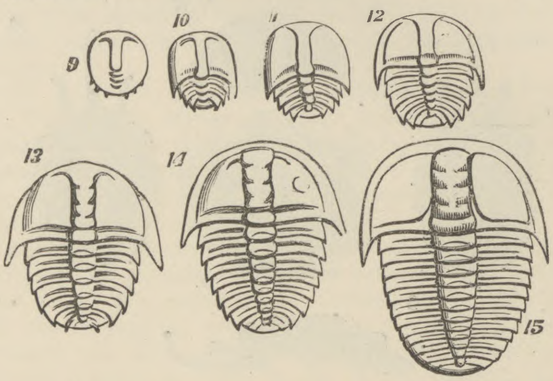


FIG. 75.—*Sao hirsuta*, Barrande (copied from pl. 7 of Barrande's work above cited). Barrande figures twenty stages of this trilobite, of which seven are reproduced here.
1. First stage. A young individual in which the limit of the head-shield is not indicated as separating it from the pygidium.
2. Second stage. Young individual with the head-shield separated, and having indications of three soldered segments to the pygidium.
3. Third stage, in which the genal angles of the head and the spiny border of the pygidium are well seen, and four or five soldered segments indicated.
4. Fourth stage, in which two free thoracic segments are developed behind the head, and two or three soldered segments represent the pygidium.
5. Fifth stage, in which the thorax is longer than the head, and is composed of three movable segments and three soldered segments in the pygidium.
6. Sixth stage, in which four free segments succeed the head, and three or four soldered segments form the pygidium.
7. Tenth stage, in which eight free segments succeed the head, and three soldered segments form the pygidium.
In the twentieth stage figured by Barrande the adult has seventeen free thoracico-abdominal segments and two soldered ones (the pygidium).

One most striking feature in the Trilobita is the remarkable development of their compound eyes (fig. 11), a subject ably discussed and illustrated long ago by Dr Buckland in his *Bridgewater Treatise* (1836).

Perhaps the eye of the Trilobite may be best compared with that of *Limulus*, but there are forms like *Æglina* in which the eyes are enormously developed, occupying nearly the entire head-shield with their facetted surfaces.

We have an analogous development of the organs of vision amongst some of the pelagic Amphipoda, the *Hyperiidæ*, and in a very singular form brought home by the "Challenger," the *Thaumops pellucida* (*Phil. Trans.* 1873). The "facial suture" in the head-shield of the Trilobita, which separates the lateral genal portion from the glabella, was for a long time considered as peculiar to Trilobites and *Limuli*, but C. Spence Bate has ably shown that it homologizes with the suture which traverses the inferior surface in the carapace of the Brachyurous Decapod and the cervical suture in the Macrouran type (*Reports Brit. Assoc.*, Bristol, 1875, p. 46.)

The Trilobita are the chief representatives of the Crustacean class in Cambrian times.[3] More than 500 species have been described; out of these 350, representing 42 genera, have been recorded from the Lower Palæozoic rocks of Bohemia alone by Barrande.

About 51 genera and 304 species are British in Cambrian[4] and Silurian rocks; ten are Devonian, and four Carboniferous. A gigantic *Paradoxides*, nearly two feet in length, occurs in the Middle Cambrian, and large forms of *Asaphus*, *Homalonotus*, *Lichas*, &c., are met in the Bala group. *Phacops*, *Sphærexochus*, *Encrinurus*, *Calymene*, *Illænus*, and *Acidaspis* are among the Upper Silurian forms,—some, like *Acidaspis*, being extravagantly ornamented with spines and tubercles. The Devonian has

[1] H. Woodward, *Report on Structure and Classification of Fossil Crustacea*, Brit. Assoc. Edinburgh, 1871.

[2] The larvæ of *Bopyrus*, *Cryptothiria*, and *Asellus*, and the adult *Ægidæ*, *Idoteidæ*, *Sphæromidæ*, and *Oniscidæ* offer many points of analogy with the extinct Trilobita (see the *History of the British Sessile-eyed Crustacea* by C. Spence Bate, F.R.S., and J. O. Westwood M.A., in 2 vols. 1863–68, 8vo.)

[3] *Agnostus*, the earliest genus met with, reminds one of the larval forms of *Sao* and *Trinucleus*.

[4] The large accession in late years to the fauna of these Cambrian rocks has resulted from the labours of Mr Henry Hicks, F.G.S.

fewer and less varied forms of Trilobites. Those in the Carboniferous belong nearly all to two genera (*Phillipsia* and *Griffithides*), both small, neat, and simple forms. None are met with in rocks of later date.

II. EDRIOPHTHALMIA : (5.) AMPHIPODA.—This order, as Spence Bate has well observed, constitutes a group among the Edriophthalmia, parallel with the Macroura among the Podophthalmia, whilst the Isopoda may represent the broad and flattened Brachyura, the *Caprellæ* offering a kind of parallelism with *Squilla* and its allies. As in the Isopoda, the head is small and carries only the organs of sense and nutrition ; the sessile eyes[1] are generally small, yet in a few instances they are extremely large (*e.g.*, *Lestrigonus* and *Thaumops*), covering the entire sides of the head.

The seven thoracic segments, constituting the middle-body, are well developed and nearly equal in size ; all the segments are compressed laterally as in the *Palæmonidæ*.

The two anterior pairs of the seven thoracic legs (see Th. 8, 9 in fig. 1), which are jaw-feet in the Podophthalmia, are here developed into arm-like legs, having an enlarged penultimate joint or hand, against which the seventh and terminal joint doubles back, like a finger against the palm, and so forms a prehensile organ similar in form to the claws in the *Crangonidæ*. The best-formed claws are seen in *Orchestia Darwinii* (fig. 45), and in *Melita exilii* (fig. 76).

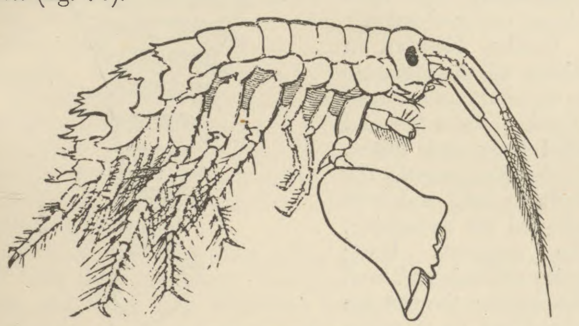


FIG. 76.—*Melita exilii*. n. sp., male, enlarged five times. The large branchial lamellæ are seen projecting between the legs. (Fritz Müller.)

The ova are nourished within a pouch formed by a series of foliaceous plates attached to the four anterior pairs of legs ; except in the *Hyperiidæ*, which are parasitic on Medusæ, as already mentioned. The males in the Amphipoda closely resemble the females (save in those forms in which the hands are enlarged in the male), but contrary to the general rule the females are much smaller than the males.

This division, like the preceding one, has its terrestrial representatives, *Talitrus* and *Orchestia*, the "sand-hoppers,"[2] living out of the sea, but choosing moist places. *Orchestia* with us loves to live within reach of the sea spray, but some species in the southern hemisphere (*O. tahitiensis*, *telluris*, and *sylvicola*) live many miles inland, some under plants at an elevation of more than a thousand feet above the sea. But by far the largest section are natatorial in their habits, being most active and untiring swimmers. One form, *Gammarus pulex* (fig. 77), is most common in our freshwaters, two other genera, both *blind*, *Niphargus*, with three species, and *Crangonyx*, with one species, are found in wells in England,[3] and from their structure there is every reason to conclude they are as truly indigenous to these underground water-courses in the Chalk, Oolite, or Carboniferous Limestone, as are the numerous species of blind Crustacea met with in the waters flowing through the Mammoth Cave, Kentucky.

FIG. 77.—*Gammarus*, sp., fresh water

A curious subdivision of Amphipods is formed by the *Podocerides* (*Amphithoë* and *Podocerus*), all the species of which invariably construct nests in which they take shelter and nourish their young. These abodes are built of wood or stones, mud, clay, &c., united together by a cement excreted by the animals themselves. Some closely resemble miniature birds'-nests, others are in the form of tubes.

This division includes another most destructive wood-borer, the *Chelura terebrans*, so devastating to piles and submarine timber all round the shores of Europe, but not recorded from other lands. Finally, we come to the minute aberrant forms of *Dulichiidæ* and *Caprellidæ* (fig. 78), in which the body is reduced to a slender elongated cylindrical form, the thorax having only about six somites (one being absent and two soldered together), and the abdomen being quite rudimentary. They have long antennæ and feet, all fitted for climbing and holding on by. Their singular appearance has caused them to be called "spectre shrimps."

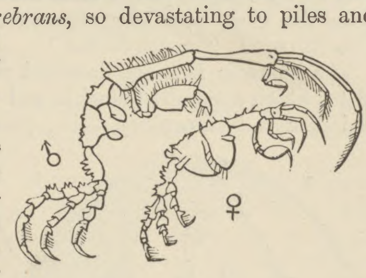


FIG. 78.—*Caprella tuberculata*, Guerin ; south coast. (Spence Bate.)

With these aberrant forms are associated the *Cyamidæ* (fig. 79), a family which affix themselves by their strong recurved legs to the rough portions of the Cetacea upon which they feed. The feet are all prehensile ; the third and fourth somites bear the branched or simple branchiæ. The abdomen, as in the *Caprellidæ*, is rudimentary ; the eggs and young are sheltered by four broad lamellar plates, developed from the appendages on the under side of the body of the female. Spence Bate and Westwood have figured five species. They approach in many respects to the Pycnogonidæ, which also live parasitic on Cetacea (see ARACHNIDA, vol. ii. p. 276–77), but we must not attempt to discuss their affinities here. A fragment of a presumed Amphipodous Crustacean has been described by the writer from the Upper Silurian (the *Necrogammarus Salweyi*) another, the *Gampsonyx fimbriatus*, occurs in the Coal-measures of Germany, Bohemia, and America. Mr Spence Bate has described one from the Permian of Durham, the *Prosoponiscus problematicus*, its modern living representative, the *Sulcator*, making peculiar tracks upon our shores to-day like those met with upon the surfaces of slabs of

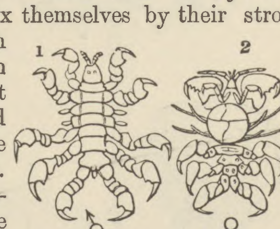


FIG. 79.—1, ♂ *Cyamus Thompsoni*, Gosse found attached to *Hyperoodon bidens*, Portland Roads. 2, ♀ *Cyamus ovalis*, Vauzeme ; found attached to common whale. (Spence Bate.)

[1] The outer integument of the eyes is never divided into facets, except in the *Hyperiidæ*. In many of the *Phoxides* the eyes appear to be wanting ; but this is probably caused by the absence of any colouring pigment. In *Niphargus* the eyes are obsolete or rudimentary. In *Ampelisca* they appear like four simple organs resembling the ocelli of true insects (Spence Bate and Westwood, *Brit. Sess. Crust.* vol. i. p. 4).

[2] It is in the summer months that they occur in such vast myriads upon our sandy shores. At Whitsand Bay Mr Twain saw "not millions, but cartloads," of one species (*Talitrus locusta*) lying piled together along the margin of the sea. They devour offal of every description, including dead carcasses of animals, which they rapidly assimilate and remove. In their turn they afford a repast to the ring-plover, the common wood-pigeon, and numerous shore-birds which rapidly devour them, as well as some coleopterous insects (the *Cillenum laterale* and *Broscus cephalotes* (Bate and Westwood).

[3] Spence Bate and Westwood (*Sessile-eyed Crustacea*, vol. iii. p. 311–328).

Palæozoic rocks. Several other Amphipod-like forms occur in the lithographic stone of Bavaria. The world-wide distribution of the Amphipoda accords well with their range in time, which was as great or even greater than the Isopoda.

Sub-class 2. GNATHOPODA (or *Entomostraca*).

III. MEROSTOMATA: (6.) XIPHOSURA.—The king-crab (*Limulus*) is a remarkable type of crustacean closely related to the extinct Eurypterida. Found living in the seas of China and Japan and on the north-east coast of North America, it exemplifies a peculiar and most ancient order, the affinities of which are not at first readily recognized because its nearest allies have passed away. The head-shield is enormously expanded so as to shelter all the anterior appendages beneath it; and the succeeding segments are so soldered together as to appear like one piece, although all the hind-segments are free and movable in the larva. The eyes are fixed on the head-shield; the antennules are chelate, and placed in front of the mouth. The antennæ, mandibles, maxillæ, maxillipeds, are all converted into walking legs, forming also chelate appendages and, at their bases, jaws; thus serving admirably to illustrate the most prominent characteristic of the sub-class GNATHOPODA, "mouth-footed."

The thoracic feet are flattened out into broad bilobed plates which cover the branchiæ and the egg-pouches. The abdomen is rudimentary, being partly represented by the

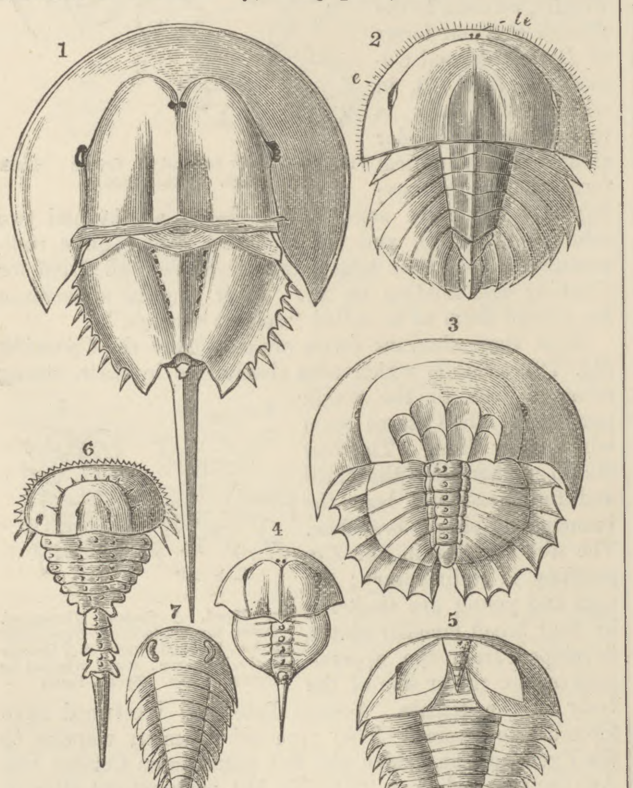


FIG. 80.—1, *Limulus polyphemus*, adult (dorsal aspect). 2, *Limulus polyphemus*, young (dorsal aspect). 3, *Prestwichia rotundata*, Coal M., Shropshire. 4, *Prestwichia Birtwelli*, Coal M., Lancashire. 5, *Neolimulus falcatus*, U. Silurian, Lanark. 6, *Hemiaspis limuloides*, L. Ludlow, Leintwardine, Shropshire. 7, *Pseudoniscus aculeatus*, U. Silurian, Russia.

posterior portion of the hinder shield, and partly by the long ensiform tail-spine (?) (See Owen's Memoir, *Trans. Linn. Soc.*, vol. xxxviii., 1873.) But in the larvæ, as has been already shown, these post-cephalic somites are free and unanchylosed, and the tail-spine is undeveloped, thus connecting the modern king-crab with its far-off ancestors in the Coal and Silurian periods. The oldest species known is the *Neolimulus falcatus*, H. Woodw. (5 in fig. 80), from the Upper Silurian of Lanarkshire, in which the segments are apparently all free and unanchylosed

In the Coal-measures no fewer than three genera and eight species of small Limuloid Crustaceans have been met with, viz. *Bellinurus* (four species), *Prestwichia* (three species), and *Euproops* (one species),—the last named an American form. Many of these closely resemble young larval *Limuli*. The Oolitic *Limuli* found in the lithographic stone of Solenhofen agree closely with existing species, one form even equalling in size the living *Limulus polyphemus* from the American coast (1 in fig. 80; see also fig. 12).

III. MEROSTOMATA: (7.) EURYPTERIDA.—In this order we become acquainted with the second extinct type of the Crustacean class, and by far the most interesting, because all the appendages as well as the body-rings have been preserved to us, whereas in the Trilobita the former are remarkable by their almost entire absence.

Unlike *Limulus*, in which all the segments in the adult are soldered together into a fore and hind body and telson, in the *Eurypterida* the body is long and well adapted for swimming, the segments being quite distinct and well developed; the feet are also fitted for natation (see 5 in fig. 73, and fig. 81).

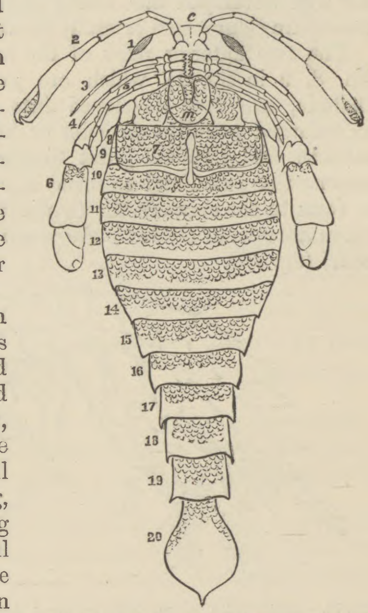


FIG. 81.—Underside of *Pterygotus Anglicus*, Ag. (restored). *c*, Cephalon; *m*, Metastoma or post-oral plate. 1, The compound eyes; 2, Chelate antennæ; 3, The mandibles; 4, First maxillæ; 5, Second maxillæ; 6, Maxillipeds; 7, The operculum or thoracic plate, which fits closely against the ventral surfaces of the two anterior thoracic somites, 8 and 9. 8-14, Thoracic somites; 15-19, Abdominal somites; 20, Telson.

We again observe the reiteration of the same well-marked characteristics in the legion Merostomata—already noticed in the Edriophthalmia and Podophthalmia; namely, the division into *Brachyuran* and *Macrouran* forms which exemplify the crawling and swimming types, by the soldering together of the body-segments in the one and the retention of free movement in the somites in the other. The characters of these two orders of the Merostomata are summarized in the subjoined table.[1]

Limulus (Fossil and living).	*Pterygotus* (Fossil, extinct).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
2. Ocelli distinctly seen.	2. Ocelli distinctly seen.
3. All the limbs serving as mouth-organs.	3. All the limbs serving as mouth-organs.
4. Metastoma *rudimentary*.	4. Metastoma *large*.
5. *All* the thoracic segments bearing branchiæ or reproductive organs.	5. *Anterior* thoracic segments bearing branchiæ or reproductive organs.
6. Other segments destitute of any appendages.	6. Other segments destitute of any appendages.
7. Thoracic segments *anchylosed*.	7. Thoracic segments *unanchylosed*.
8. Abdominal segments *anchylosed and rudimentary*.	8. Abdominal segments *free and well developed*.

Numerous species of these ancient extinct long-bodied Merostomata have been met with and described by Hall in

[1] Taken from H. Woodward's Report on the structure and classification of the fossil Crustacea (*Brit. Assoc. Reports, Edinburgh*, 1871).

America, by Fischer in Russia and Sweden, and by Huxley, Salter, and Woodward in Britain (see H. Woodward's monograph in Pal. Soc., 4 parts, 1865–1872).

The most perfect specimens of the genera *Slimonia*, *Pterygotus*, and *Eurypterus* have been obtained by Dr J. Slimon of Lesmahagow, Lanark. The largest known remains, representing specimens from 5 to 6 feet in length, are from the Devonian of Forfarshire, belonging to the great *Pterygotus anglicus* and to *Stylonurus scoticus* obtained by Mr James Powrie, F.G.S., Reswallie, Forfar.

In the Upper Silurian we have one English genus, *Hemiaspis* (6 in fig. 80), and three Russian forms, *Exapinurus*, *Pseudoniscus* (7 in fig. 80), and *Bunodes*, which, like the Anomoura, serve to bridge over the interval between the *Limuli* and *Pterygoti*, the hind-body being partially developed. The best illustration of the Eurypterida is to be found in the zoëa of the common shore-crab, *Carcinus mænas* (figs. 26 and 27), in which the principal locomotory organs are the maxillipeds, and the abdominal somites are destitute of all appendages. The latest representative of this extinct order has been found in the Lower Carboniferous series of West Lothian, the *Eurypterus Scouleri*, which however differs greatly from all the other forms.

IV. Branchiopoda: (8.) Phyllopoda.—This order includes not only the bivalved *Estheria* and *Nebalia*, and the shield-bearing *Apus*, but two forms of naked gill-footed Crustacea, *Branchipus* and *Artemia* (5 in fig. 57). Of the shield-bearing forms the fresh-water *Apus* may serve as a good example. The eyes are placed in front on the dorsal surface of the carapace and are nearly confluent. The first pair of feet (maxillipeds) are long and branching; to these succeed about sixty pairs of branchial feet. The thoracic and abdominal somites are nearly cylindrical and are composed of about thirty articulations, terminated by two long, many-jointed tail-spines.

Probably *Apus* has more articulations to its appendages and body than any other Crustacean. Schäffer tabulated them, and found they numbered 1,802,604; Latreille puts them down at not less than 2,000,000. *Apus* affords an excellent illustration of a form in which the mere vegetative repetition of parts is carried to an extreme distance beyond the normal number of body-rings so characteristic of the class.

In *Nebalia*, the marine type (1 in fig. 57), the carapace or head-shield has a well-marked rostrum, and is more compressed laterally than in *Apus*, covering the head and thorax and even a part of the abdomen. The eyes in *Nebalia* are placed on peduncles beneath the carapace; the number of segments is not excessive as in *Apus*.

In *Estheria* (fig. 56), the carapace is composed of two valves, subovate in outline, like a bivalve molluscan shell, which it also resembles in being united by the umbones of each valve on the anterior dorsal border, and in each valve being marked by regular concentric lines of growth.

Branchipus (5 in fig. 57) and *Artemia* are destitute of any carapace, so that the elegant wave-like motion of their many-jointed transparent bodies and branchial feet can be freely observed. The former inhabits our fresh waters, the latter is marine, being peculiarly prolific in the brine-pans at Lymington, where the workmen firmly believe that the "brine-shrimp" aids in some way the rapid deposit of salt, through the constant agitation caused by such myriads of these minute and restless Entomostraca in the water.

Chirocephalus or *Branchipus* is believed to be only a variety of *Artemia*, resulting from change of conditions between a fresh and an extremely saline fluid medium.[1]

[1] See M. W. J. Schmankewitsch's paper on the transformations of *Artemia* and *Branchipus*, *Ann. and Mag. Nat. Hist.* vol. xvii. March 1876.

In Professor T. Rupert Jones's monograph on fossil *Estheriæ*, out of thirty-eight localities recorded for that genus living, three only were met with in brackish water.

Mr John Arthur Phillips, F.G.S., states that the *Artemia fertilis* is exceedingly abundant in the highly-saline waters[2] of Mono and Owen's Lakes, California. These little Crustacea congregate in such dense serpentine or annular masses in the water that a breeze sufficient to ruffle the surface of the lake scarcely affects the water filled by the *Artemiæ*, which remains perfectly smooth. The only other inhabitant of these salt-lakes is the larva of a dipterous insect, the *Ephydra californica*, Torrey, which is collected by the Indians, and, when dried in the sun, forms an important article of food. Myriads of gulls and other aquatic birds visit these lakes in summer to feed upon the *Artemiæ* and larval *Ephydræ*.

Nebalia, at the present day, seems but the puny and degenerate representative of the once giant pod-shrimps of Silurian times, the caudal somites of one of which measured 8 inches and the tail spines 6 to 7 inches in length, the carapace not being preserved.[3] The ancestors of *Nebalia* date back to the Menevian group, *Hymenocaris major* being the earliest known. *Ceratiocaris papilio* is so abundant in the Upper Silurian of Lesmahagow, Lanark, as to cover entire beds with its remains.

Many fossil forms, as *Dithyrocaris*, *Discinocaris*, *Aptychopsis*, and *Peltocaris*, carried their head-shield flat and expanded like *Apus* at the present day; one of these, a *Discinocaris* from Moffat, Dumfriesshire, had a carapace 7 inches in diameter. These forms occur in all the Palæozoic rocks. *Estheriæ* are found in the various strata from the Carboniferous Limestone to the Tertiary. Although *Branchipus* or *Chirocephalus* is destitute of any head-shield, its fossil remains have just been transmitted to the writer together with numerous Dipterous and Coleopterous insects from a freshwater deposit, associated with plant remains, at Gurnet Bay, in the Isle of Wight.

IV. Branchiopoda: (9.) Cladocera.—In the Cladocera are placed a number of minute animals furnished with branching natatory antennæ and five or six pairs of short foliaceous feet; the body (except the head which is distinct and projecting) is entirely inclosed within a carapace, formed of two valves joined together on the back; the eye is single and very large. The Cladocera are chiefly freshwater, and are distributed over the whole world. Of this order the *Daphnia pulex* (1 in fig. 58), so abundant in our fresh waters, is a good example. So numerous are they in our ponds in summer as frequently to impart a blood-red hue to the water for many yards in extent. In order to realize the wonderful fecundity of this and allied genera,[4] it is necessary to realize that when a *Daphnia* is only ten days old, eggs commence to be formed within the carapace, and under favourable conditions of light and temperature, it may have three broods a month or even a greater number,—the larger species having as many as forty or fifty eggs at once. No males appear until the autumn, so that all the earlier broods are derived from females, whose parent was fertilized, and died after depositing its eggs, the year before, and these continue to reproduce fertile female offspring throughout the summer.

[2] In 1866 Mr Phillips found that the waters of Owen's Lake had a specific gravity of 1·076, and contained 7128·24 grains of solid matter per gallon. This solid matter held in solution consisted of chloride, sulphate, and carbonate of sodium, 6813·28; sulphate, phosphate, and silicate of potassium, 298·02; and organic matter, 16·94 grains per imperial gallon.

[3] See *Geol. Mag.* 1866, vol. iii. pl. 10. fig. 8, p. 203; and *Geol. Mag.* 1871, vol. viii. pl. 3. fig. 3, p. 104.

[4] See Memoir by Professor Leydig, *Naturgeschichte der Daphniden*, 4to. Tübingen, 1860; Sir John Lubbock in *Phil. Trans.* 1857; Baird's *British Entomostraca* (Ray cieSoty).

F. Goldenberg has lately described a fossil form belonging to this division (*Lyncites ornatus*) from the Coal-measures of Saarbruck.[1]

V. Lophyropoda: (10.) Ostracoda.—In the Ostracoda, of which *Cypris*, *Candona* (2 in fig. 58), and *Cythere* are examples, the body is entirely enclosed in a carapace composed of two nearly equal parts like a bivalve shell. Two pairs of antennæ, one pair long, with hairy filaments, one pair short, stout, and recurved (like feet), and three pairs of short feet, may be seen protruded from the carapace, which is compact and brittle, yet is capable of protecting the living animal during long periods of drought, buried in the dried-up mud of pools. *Cypris* frequents stagnant water, living on dead animal matter. *Cythere* is found in pools along the sea-shore.

Like the Phyllopoda, the Ostracoda are of immense geological antiquity, *Primitia prima* occurring in the Lower Cambrian of St David's. There is abundant evidence, in almost every stratum, of the former existence of these little bivalved Crustacea, often in vast numbers; their size in early times was much larger, *Leperditiæ* as big as large horse-beans being found in Silurian strata, but the living forms are all microscopic. M. Ch. Brongniart has just described a fossil Ostracod, *Palæocypris Edwardsi*, inclosed in silex from the coal of St Étienne, in which all the organs are most perfectly preserved.[2] It closely resembles the modern form. The Ostracoda help with other microscopic organisms to build up the Chalk. They make up the great mass of the *Cypris* shales of the Wealden, Isle of Wight, and many Tertiary beds are largely composed of their remains.

V. Lophyropoda: (11.) Copepoda—(*a.*) Liberata.—The free Copepods, of which *Cyclops*, *Canthocamptus*, and *Cetochilus* may serve as examples, have the head and thorax closely enveloped in a carapace with which the front rings of the thorax are confluent. The abdominal somites are much diminished in size and cylindrical. The single or paired external ovisacs are attached to two of the posterior somites, which are usually welded together. The single sessile median eye is situated near the front of the head; in the males of *Diaptomus* and *Anomalocera* the eye is pedunculated. The antennæ are very long and powerful natatory organs (in *Cetochilus*, 4 in fig. 58, and *Diaptomus* equalling the entire length of the animal's body); in the males one or both of the antennæ have a swelling near the centre or towards the extremity, followed by a movable joint which acts like a hinge and serves as a clasper to detain the female. There are five pairs of rowing feet, one pair of which are usually rudimentary.

The species belonging to this family are to be found in both fresh water and the sea. In the muddiest and most stagnant pools and in the clearest springs *Cyclops* abound (3*a* in fig. 58). The marine species frequent the pools along shore and the open ocean in equal abundance. They assist in producing that luminous appearance in the sea called "phosphorescence," for want of a better name (5 in fig. 58).

The fecundity of this order is truly surprising. *Cyclops quadricornis* is often found with thirty or forty eggs on each side; and though those species which have but a single ovisac do not carry so many, their number is still very considerable. Jurine isolated female specimens of *Cyclops*, and found them to lay eight to ten times within three months,—each time about forty eggs. At the end of a year one female would have produced 4,442,189,120 young! *Cetochilus* (4 in fig. 58) is so abundant, both in the Northern Seas and in the South Atlantic, as to serve for food to such an immense animal as the whale. They colour the sea for many miles in extent, and when the experienced whaler sees this ruddy hue upon the ocean he knows he has arrived at the "pasture of the whales." They are to be seen in vast quantities off the Isle of May in the Firth of Forth during the summer months; many Cetacea are attracted thither, and vast shoals of fish also come to feed upon them. One anomalous type of free Copepods is the *Notodelphys acidicola*, described by Allman, which is found swimming freely in the branchial sac of the *Ascidia communis.* In this species the female has the fourth anterior segment of the body peculiarly modified, so as to form on its dorsal surface a marsupium for receiving and retaining the ova until they are hatched, when they escape by an opening between the sac and the upper surface of the body-ring.

We have no positive records of Copepoda occurring in a fossil state.

V. Lophyropoda: (11.) Copepoda—(*b.*) Parasita.—The parasitic Copepods are divisible into two groups, the first comprising the peripatetic genera, in which the male and female both retain their organs of locomotion in the adult state, and can change their habitat whenever needful; this division would include the fresh-water *Argulidæ* and the marine *Caligidæ*. The second division embraces the fixed parasites, in which the females when adult lose their locomotory appendages and become fixed, deriving their nourishment by a true suctorial mouth, armed with styliform mandibles, from the fishes and other animals upon which they are parasitic. The larvæ when they emerge from the egg are nauplii, like those of other Copepods. The males and females are then alike; after attachment the female often attains a large size, and is soon little more than a maggot-like body, with immense paired ovaries attached to her abdomen. The male is very small and resembles a fat *Acarus*; he is usually parasitic on the female, adhering to the vulva.

Almost every fish has some form of these Copepod parasites, either on its skin, its eyes, or its gills.

Argulus foliaceus is of a rounded oval shape, the carapace inclosing the thoracic somites in a deep notch behind, and the body terminating with a bilobed telson. The antennæ are formed into recurved hooks for holding on by, when the animal shifts its position. The second pair of foot-jaws are converted into powerful suckers by which it attaches itself to its host. The mouth is tubular, and has a sharp styliform organ within it, affording good evidence of its suctorial habits. There are four pairs of biramose natatory feet. The animal, when detached, swims with extreme rapidity and elegance, and no fish, however rapid, can escape from its adherence.

The female is much larger than the male. She leaves the fish on which she is parasitic when desirous to deposit her eggs, which she fixes to a stone or other inorganic body at the bottom of the water. As many as 400 are deposited at one time by a single female. *Argulus catostomi* is said to lay 1500 eggs at once. The young are hatched in thirty-five days, and after about three moults as free Copepod larvæ they put on the adult form.

It would be impossible to give a detailed account of all the varied forms of Copepoda in an article like the present; we therefore must refer the reader to the works of Baird, Claus,[3] and others for fuller information.

VI. Anchoracephala: (12.) Rhizocephala.—These have been referred to under Metamorphosis, so that we need not allude to them further here, save only to give illustrations of two genera, *Peltogaster* (fig. 82) and *Sacculina* (fig. 83).

VI. Anchoracephala: (13.) Cirripedia.—Forty years

[1] *Giebel und Siewert's Zeitschrift*, 1870, vol. i. p. 524.
[2] *Ann. des Soc. Geol. France*, t. vii. pt. vi.
[3] See Dr C. Claus, *Die Frei Lebenden Copepoden mit Besonderer Berücksichtigung der Fauna Deutschlands der Nordsee und des Mittlemeeres*, 37 plates, Leipsic, 1863, 4to.

ago the Cirripedia were still arranged as Mollusca in many public museums; nor is this surprising, considering the

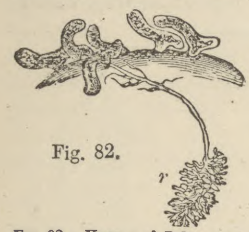


Fig. 82.


Fig. 83.

FIG. 82.—Young of *Peltogaster socialis* on the abdomen of a small hermit-crab; in one of them the fasciculately ramified roots, *r*, in the liver of the crab are shown. The animal and roots are deep yellow. (Fritz Müller.)
FIG. 83.—Young of *Sacculina purpurea* with its roots; the animal purple-red, the roots dark grass green. Magn. 5 diam. (Fritz Müller.)

fixed condition of their shells and the degree of external resemblance between *Lepas* and *Teredo* on the one hand, and *Balanus* and a compound of a *Patella* and a *Chiton* shell on the other. Strauss in 1819 first affirmed that Cirripedes were Crustacea. But this view was disregarded until J. Vaughan Thompson's capital discovery in 1830 of their metamorphosis, since which time they have been almost universally placed with the Crustacea.

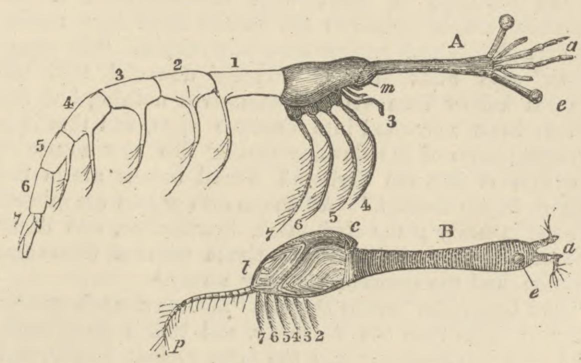
The Cirripedia are classed by Darwin in three great divisions:—(1) THORACICA (limbs thoracic); (2) ABDOMINALIA (limbs abdominal); (3) APODA (appendages wanting). In the first division are embraced the *Balanidæ*, the *Verrucidæ*, and the *Lepadidæ;* in the second a single genus, *Cryptophialus minutus;* the third is also represented by one form, the *Proteolepas bivincta*.

(1) THORACICA.—Cirripedes ordinarily are bisexual,[1] in which respect they differ from all other Crustacea,—the male (where it exists distinct) being minute and rudimentary in structure and permanently epizoic on the female. In these latter facts we find an analogy in the Copepoda Parasita just noticed. The male has the excretory organ single, median, and probosciform, and placed at the extremity

FIG. 84.—1, *Scalpellum rostratum*, Darwin, Philippine Islands; 2, *Pollicipes cornucopiæ*, Leach, European Seas; 3, *Tubicinella trachealis*, Shaw, attached to whales; 4, *Acasta sulcata*, Lamk., in sponges, New South Wales (4′, tergum; 4″, scutum); 5, *Balanus tintinnabulum*, Linn., Atlantic; 5′, Section of *Balanus*, Linn.; 6, *Coronula diadema*, Linn., attached to whales.

of the abdomen,—in all these respects differing from other Crustacea in which the male organ is laterally double. In the female organs the ovarian tubes and cæca inosculate together; there are no oviducts, the ova connected together by membrane, and so forming the "ovigerous lamellæ," become exposed by the exuviation of the lining tunic of the carapace or sack, and by the formation of a new tunic on the under side of the lamellæ, a process unknown in any other Crustacean. The Thoracica are mainly divided into *Balanidæ* and *Lepadidæ;* in the former, the animal when adult is inclosed in the parietes of its shell, and fixed to some living or dead object by a broad shelly basis, the aperture being protected by the opercular valves. In the *Lepadidæ* the animal is attached by the extremity of a more or less long muscular peduncle, and its body is lodged within the shelly valves of the capitulum. In some species, as in *Pollicipes* and *Scalpellum*, the peduncle is covered with more or less numerous rows of scales or squamæ. This peduncle in *Pollicipes* and *Scalpellum* corresponds with the basis in *Balanus*, as may clearly be seen if a *Pollicipes* with a short peduncle and a *Balanus* with a deep cup-formed or cylindrical basis be compared, the animal being in part lodged in both, as in *Ibla* and *Lithotrya*. The scales which surround the base of the valves in *Pollicipes* correspond with the parietes of the walls of *Balanus*, the valves of the capitulum of the former being homologous with the opercular valves in the latter (fig. 84). The body consists of six, perhaps of seven, posterior thoracic somites. In the division Thoracica the abdomen is undeveloped.[2] The thoracic segments support six pairs of cirri. Each cirrus consists of a two-jointed pedicel, carrying two multi-articulated rami. The mouth has a labrum, palpi, mandibles, and two pairs of maxillæ; within the sack a folded membrane forms the branchiæ. Darwin concludes that in the Cirripedia the body may be said to be composed, at most, of but seventeen segments.

In order to indicate the homologies which still exist between the parts of an adult Cirripede and an ordinary free



85.—Theoretical view of the homologies of the Cirripedia with other Crustacea. A, *Leucifer* (a Stomapod); B, *Lepas*. *a*, antennæ; *e*, *e*, the eyes; *m*, the mouth; *p*, the penis. (After Darwin.)

Crustacean, we give the accompanying illustrations from Darwin (fig. 85). The upper figure is a Stomapod Crustacean (*Leucifer*); the abdomen, being rudimentary in the adult Cirripedia, is only shown in faint outlines. The lower figure is of a mature *Lepas* with the antennæ and eyes, which are actually present in the larva, retained for the sake of completing the comparison. "All that we externally see of a Cirripede, whether pedunculated or sessile, is the three anterior segments of the head of a Crustacean, with its anterior end permanently cemented to a surface of attachment, and with its posterior end projecting vertically from it" (Darwin).

The thoracic appendages of the Cirripedia present us with yet another wonderful modification of the Crustacean type; these biramous multi-articulated cirri are neither natatory, nor ambulatory, nor branchial, but "captorial," or fitted for sweeping the water, and thus catching prey,—their alternate extensile and retractile wave-like movements bringing all floating particles and minute organisms within reach of the inclosed mouth.[3]

[1] All the *Balanidæ* are bisexual and hermaphrodite, no males or complemental males having been found in any of them.

[2] In the pupa, however, of this order, and in the mature animal of the two other orders (the *Abdominalia* and *Apoda*), it is formed of three segments.

[3] Mr Gosse mentions that the little crab, *Porcellana platycheles* (fig.

(2) ABDOMINALIA.—The single Cirripede, the *Cryptophialus minutus*, forming this section is the smallest known, being less than $\frac{1}{10}$th of an inch in length. It is met with imbedded in vast numbers in the living shell of *Concholepas Peruviana*, the crypts almost touching each other. The three abdominal somites bear three pairs of cirri, the thoracic somites being apodal. The sexes are distinct, the minute almost globular male being lodged within the crypt occupied by the female. Darwin found from one or two up to seven males attached to the same female.

(3) APODA.—This section, like the last, contains only a single form, the *Proteolepas bivincta*, resembling the larva or maggot of a fly attached by two threads; the mouth is suctorial; it has no limbs; its body is shell-less, and it lies parasitic within the sack of *Alepas cornuta*.

Cirripedia occur attached to the most varied objects, living and dead, throughout the seas of the globe. Sessile forms like *Tubicinella*, *Coronula*, *Platylepas*, *Chelonobia*, &c., are found attached to, and imbedded in, the epidermis of the whale, and on the shell of the turtle, &c. Pedunculated forms are similarly widely distributed. Fritz Müller calls attention to one anomalous form described by Darwin, the *Anelasma squalicola*, parasitic upon sharks in the North Sea, which seems to offer a remarkable analogy to the Rhizocephala. This Lepadide, he says, seems in a fair way to lose its cirri and buccal organs altogether. "The widely-cleft shell-less test is supported upon a thick peduncle, which is imbedded in the skin of the shark. The surface of the peduncle is beset with much-ramified hollow filaments, which penetrate the shark's flesh like roots." Cement glands and cement were not visible. "It seems to me," says Fritz Müller, "hardly doubtful that the ramified hollow filaments are themselves nothing but the cement ducts converted into nutritive roots, and that it is in consequence of the development of this new source of nourishment that the cirri and buccal organs are in the highest degree aborted." All the mouth organs are minute and rudimentary; the cirri thick, inarticulate, and destitute of bristles; the muscular tissue without transverse striation, and the stomach perfectly empty.[1]

"The *Lepadidæ*," writes Darwin, "include a much greater range of forms than the *Balanidæ*, and this is what might have been expected, for it is the most ancient family, and extinction has done its work in separating genera which, according to analogy, were once more nearly connected by intermediate forms."

The most ancient sessile Cirripede found fossil is the *Pyrgoma cretacea*, H. Woodw., from the Chalk. Previous to 1865 the oldest-known pedunculated Cirripede was the *Pollicipes rhæticus*, Moore. In that year the writer described a curious and most anomalous form of Cirripede, from the Upper Silurian of Dudley, with imbricated calcareous plates (fig. 86), under the name of *Turrilepas Wrightii*, previously described as a *Chiton*. The fossil form with which it has been compared is more perfect and equally bizarre, viz., the *Loricula pulchella* (see 6 in fig. 70), originally discovered in the Chalk of Rochester and since in that near Norwich. It affords evidence of a most aberrant form of Lepadide, in which the capitulum is very small; the body of the animal was lodged in a broadly-expanded peduncle, clothed in five rows of smooth loricated calcareous scales, which, if both sides were perfect, would have possessed ten rows and the plates would have exceeded 200 in number. In Bate and Westwood's *Sessile-eyed Crustacea* (vol. ii. p. 268) is figured a larval form of *Cryptothiria Balani* (reproduced in fig. 41 above), which seems to afford evidence of a similar arrangement of plates. Possibly *Loricula* was parasitic like *Bopyrus*.

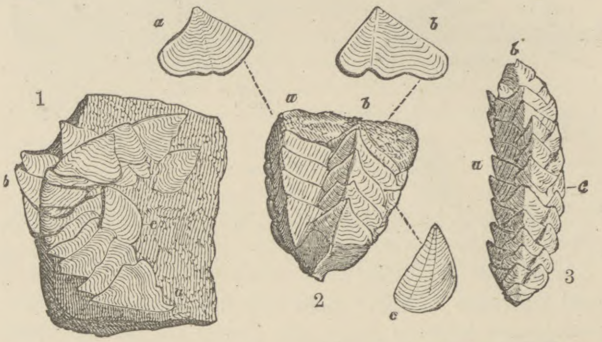


FIG. 86.—*Turrilepas Wrightii*, H. Woodw. (*Chiton Wrightii*, De Kon.); U. Silurian, Dudley. The detached figures, *a*, *b*, *c*, indicate the three forms of plates of which the peduncles are composed in 1, 2, and 3 which bear the corresponding letters. The opercular valves are not known.

In conclusion, sufficient evidence has been adduced to show that the normal development of the Crustacean class has been one of progressive advancement, the forms of to-day, when viewed as a whole, being more highly developed and more differentiated than those which the geological record has preserved to us. But in any large community or class it is only the few that outstrip the many in the struggle for existence. Thus the Podophthalmia and Edriophthalmia present numerous examples of high advancement, both in intelligence and in attaining to a terrestrial life, especially in the Decapoda-Brachyura. The Ostracoda, Phyllopoda, and Xiphosura are good instances of merely persistent forms. They are orders the members of which have branched out long since into by-ways of their own, where, being checked from further progress, they have, by their great tenacity of life and large powers of reproduction, held their ground through the long lapse of ages from Silurian times to the present day, whilst higher orders have been modified or swept away.

But the history of some Crustacea has been *retrogressive*, probably in a few instances from arrested larval development, as, for example, in the case of the imperfectly-developed fifth pair of legs in *Porcellana*, *Galathea*, and *Munida*; in most instances, however, retrogression seems clearly traceable to the parasitic or sedentary mode of life which the members have adopted. We have examples of this in the loss of eyesight in Crustacea passing their lives in subterranean caverns, wells, and streams; the loss and atrophy of a part of the defensive armature of the body in the burrowing *Thalassinidæ*; the complete loss of the abdominal calcareous covering in *Pagurus*; the general atrophy of limbs and loss of symmetry of the body in the *Bopyridæ* through residence within the branchial chambers of other Crustacea; and the complete or partial loss of all or nearly all recognizable Crustacean characters in the adult female, or in both sexes, by parasitism on Crusacea, fishes, &c., in certain of the *Bopyridæ*, in the Copepoda, in the Rhizocephala, and in the Cirripedia.

Viewed as a whole, the Crustacea probably offer the best illustration of a class constructed on a common type, retaining its general characteristics, but capable of endless modifications of its parts, so as to suit the extreme requirements of every separate species.

The outline of this great class here attempted necessarily lacks many important details; these must be filled in by the reader from the various works referred to throughout the article. (H. W.)

68), which lives concealed, holding tightly to the under side of flat stones at low water, does exactly the same thing with its maxillipeds as the barnacles do with their cirri; it keeps up a semicircular sweeping movement, so that a constant current conveys all the small living and dead objects within reach of its mouth.

[1] Fritz Müller, *op. cit.* p. 140, and Darwin, *op. cit.* p. 170, Pl. 4, figs. 1–7.