

larva (fig. 24 A) is from 2 to 2.25 mm. in length. The thorax is fully segmented and is entirely covered by the carapace. The abdomen (*Ab*) is either unsegmented and entirely united with the telson (*Tel*)

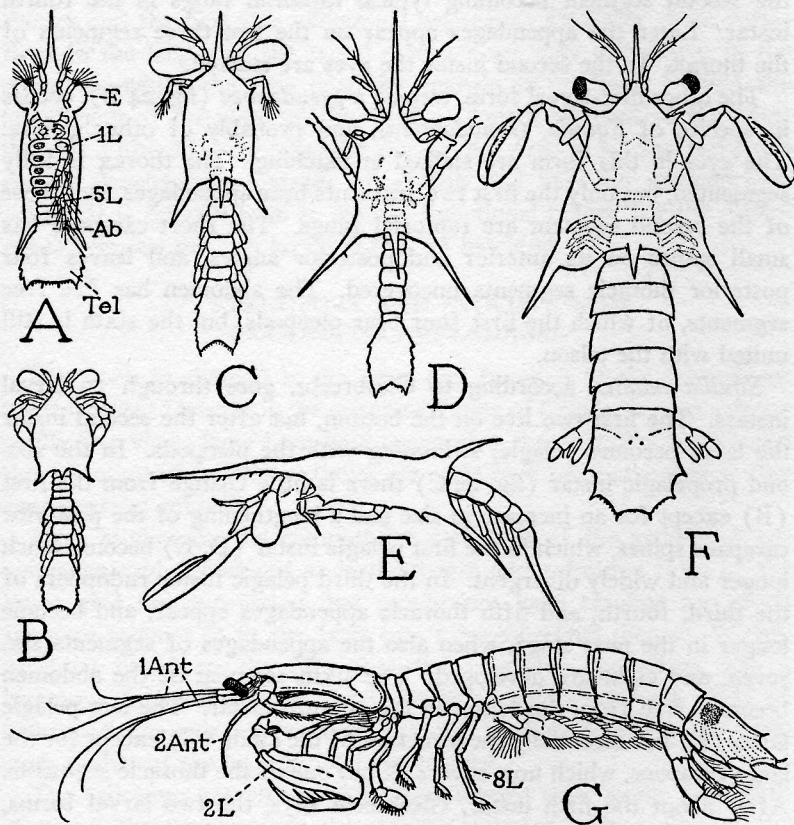


FIG. 24.—Stomatopoda. Larval stages and an adult. (A-E from Giesbrecht, 1910; F from Alikunhi, 1952.)

A, an antezoea larva. B, *Squilla mantis* Latr., first propelagic stage. C, same, second propelagic stage. D, same, first pelagic stage, dorsal. E, same, first pelagic stage, lateral. F, *Squilla latreillei*, last pelagic larval stage. G, *Squilla mantis*, adult male.

Ab, abdomen; *1Ant*, first antenna; *2Ant*, second antenna; *E*, eye; *1L*, *2L*, *5L*, *8L*, first, second, fifth, and eighth thoracic appendages; *Tel*, telson.

in a wide, fan-shaped plate, or one or two anterior segments may be free. The eyes (*E*) are large but sessile. The first five thoracic segments bear each a pair of small, biramous appendages (*1L*, *5L*) used for swimming. The antezoeal larva is pelagic. During subsequent

stages of its growth, the abdominal segments are successively separated from the telson and acquire pleopods. The five thoracic appendages lose their exopodites and take on the adult form, those of the second segment becoming typical raptorial fangs in the fourth instar. Later the appendages appear on the last three segments of the thorax. In the second instar the eyes are stalked.

The other first-larval form, termed a *pseudozoea* (fig. 24 B), occurs in species of *Squilla*, *Gonodactylus*, and probably of other genera. The eyes in this form are stalked at hatching. The thorax is fully segmented, but only the first two segments bear appendages, and those of the second segment are raptorial fangs. The short carapace has small spines on its anterior and posterior angles, and leaves four posterior thoracic segments uncovered. The abdomen has five free segments, of which the first four bear pleopods, but the sixth is still united with the telson.

Squilla mantis, according to Giesbrecht, goes through 10 larval instars. The first two live on the bottom, but after the second instar the larva becomes pelagic, swimming with the pleopods. In the second propelagic instar (fig. 24 C) there is little change from the first (B) except for an increase in size and a lengthening of the posterior carapace spines, which in the first pelagic instar (D, E) become much longer and widely divergent. In the third pelagic instar rudiments of the third, fourth, and fifth thoracic appendages appear, and become longer in the next stage, when also the appendages of segments six, seven, and eight are developed. The sixth segment of the abdomen becomes free from the telson in the seventh instar. The last pelagic larva (F) has essentially the structure of the adult (G) except for the large carapace, which now covers all but one of the thoracic segments. After about the fifth instar, Giesbrecht says, the two larval forms, originating with the antezoea and the pseudozoea, become structurally alike.

The principal structural changes during the life of the stomatopod take place at the transformation of the larva (fig. 24 F) into the adult (G). Even here, however, the only essential change affects the carapace, which is much shortened and narrowed and loses its posterior spines. Instead of covering most of the thorax as in the larva (D, F) the carapace of the adult leaves the last four thoracic segments exposed. In this respect the carapace reverts to its relative length in the first propelagic larva (B). It is evident, therefore, that the larval development of the back shield is a metamorphic adaptation to the pelagic life of the larva, probably to assist in keeping the larva afloat. The relative length of the larval carapace varies in different

species. In some forms the last four thoracic segments are not covered, as in the adult of *Squilla* (G), in others such as *Squilla latreillei* (F) only the eighth segment is exposed in the larva, while in species of *Lysiosquilla* the carapace of the last larva may cover the entire thorax and the first two abdominal segments. Probably these variations in the length of the larval carapace are only differences in the extent to which the free posterior margin is produced beyond the attachment of the plate on the third or fourth segment of the adult thorax. Otherwise the changes during the growth of the larva are merely developmental stages of growth and have no metamorphic value. It is difficult even to see any functional reason for the differences between the two larval forms on hatching.

IV. STRUCTURE AND EVOLUTION OF ARTHROPOD APPENDAGES

Inasmuch as changes in the form and function of the appendages are important features in the metamorphoses of Crustacea, and various conflicting views have been held concerning the primitive nature and the evolution of arthropod limbs, we must give some attention to this controversial subject.

Most studies on the comparative structure of the arthropod appendages, and deductions as to the origin and primitive form of the limbs give the impression that conclusions have resulted too much from an attempt to fit the facts into a preconceived theory. Widely accepted has been the idea that the primitive appendage was a biramous limb; and many carcinologists would derive all kinds of arthropod appendages from an original phyllopodial type of limb, such as that of the branchiopod crustaceans.

The trilobites are among the oldest known arthropods, and, with respect to their appendages, they are the most generalized, since all the postoral limbs are fully segmented legs. The base of each leg bears a branched lateral process (fig. 25 A, *Eppd*), which, arising on the coxa, is clearly an epipodite and hence cannot be an equivalent of the crustacean exopodite, which by definition is an exite of the basipodite. The trilobite limb, therefore, is not "biramous" in the manner of a crustacean limb, and hence does not relate the trilobites to the Crustacea. Raymond (1920), however, explicitly states the opposite view. "The trilobites," he says, "are themselves crustaceans, as is amply proven by their biramous appendages." More recently, Heegaard (1947) has argued that the trilobite limb is truly biramous, in spite of the evident coxal position of the "exopodite," and he further attempts to show that remnants of a primitive biramous structure are

to be found in various modern arthropods other than the Crustacea. His discussion, however, takes too many liberties with simple visible facts in an endeavor to fit them into a consistent scheme of structure. The studies of trilobite appendages by Störmer (1939) leave little doubt that the trilobite leg (fig. 25 A) is simply a uniramous, segmented limb with a coxal epipodite that was perhaps a gill. Störmer's contention, however, that a narrow ring at the base of the coxa is a

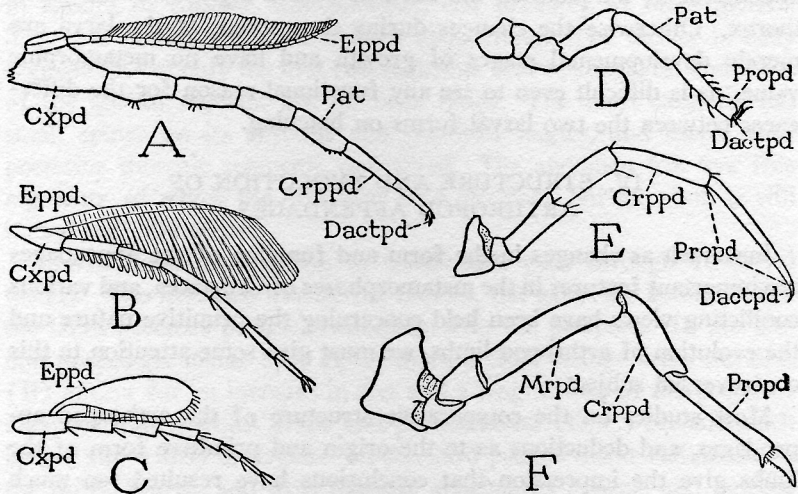


FIG. 25.—Examples of segmentation of arthropod legs.

A, leg of a trilobite (from Störmer, 1939). B, leg of *Marella* (adapted from Walcott, 1931). C, leg of *Burgessia* (from Walcott, 1931). D, leg of solpugid arachnid. E, leg of a chilopod, *Lithobius*. F, leg of a decapod, *Cambarus*.

Crppd, carpopodite (tibia); *Cxpd*, coxopodite (coxa); *Dactpd*, dactylopodite (pretarsus); *Eppd*, epipodite; *Mrpd*, meropodite (femur); *Pat*, patella; *Propd*, propodite (tarsus).

precoxal segment is questionable. The coxa of other arthropods is often marked by a circular groove near the base that forms an internal strengthening ridge giving attachment to the body muscles of the limb. In the trilobite leg the large coxopodite should be the movable basal segment of the limb and not the narrow "precoxa."

The idea that the primitive arthropod limb was a flat, lobulated appendage of the phyllopodial type has been accepted by some carcinologists regardless of the fact that the limbs of the trilobites (fig. 25 A) and of associated fossil forms such as *Marella* (B) and *Burgessia* (C) are slender jointed legs, as are those of nearly all modern arthropods (D, E, F), including the Malacostraca (F).

Walcott (1931), for example, in discussing his Burgess Shale fossils seems to accept this theory without question when he says: "The biramous limb of *Marella*, like that of the trilobite, undoubtedly passed through the foliaceous or multiramous limb stage in its evolution, probably in pre-Cambrian time." There is no disproving this idea, which should apply to the other arthropods as well, but such implicit faith in a theory is hard to understand.

On the other hand, Raymond (1920) says the theory of the phyllopod origin of the arthropod limb "has been completely upset" by the finding of such "undoubted branchiopods" as *Burgessia* in the Middle Cambrian with trilobitelike legs. The same idea has been expressed by Heegaard (1947) in his statement that the "undoubted branchiopods" found by Walcott in the Middle Cambrian having trilobite legs show that "it can no longer be held that the phyllopodial limbs are primitive." The writer fully agrees with this conclusion, but for different reasons than those given by Raymond and Heegaard. Such fossils as *Burgessia* and *Marella* are certainly not "undoubted" branchiopods. Walcott (1931) says of *Marella* that it is a less primitive form than the Apodidae and more primitive than the trilobites, but is nearer to the latter than to the former. Among the Middle Cambrian fossils, however, is a form, *Opabina regalis* Walcott, particularly studied by Hutchinson (1930), which evidently is an anostracan branchiopod with foliaceous appendages.

Another popular belief concerning the derivation of the arthropod limb, taken to support the theory of its biramous phyllopodial origin, is that the limb was evolved from the polychaete parapodium. Reasons have already been given in section I of this paper for believing that the annelids have only a remote connection with the arthropod progenitors. Certainly the arthropods can have no relation to modern polychaetes, which are highly specialized annelids and could give rise only to more polychaetes. The appendages of the worm, though they are bilobed flaps, have a lateral position on the body (fig. 26 A), and there is nothing in their structure having any likeness to an arthropod limb at any stage of its development. The parapodium bears two bundles of bristles supported on a pair of long internal rods giving attachment to muscles. Its only common feature with an arthropod limb is that, being a locomotor organ, it is movable forward and backward by body muscles. In short, the idea that the arthropod appendages were derived from annelid parapodia appears to be just another case of excessive zeal for generalization.

Among modern wormlike animals those closest to the arthropods are the Onychophora; some zoologists have even included the ony-

chophorans in the Arthropoda. Though a modern onychophoran shows no external segmentation of the body in the adult stage, the segmented repetition of internal organs and the complete body segmentation of the embryo leave no doubt that the Onychophora are

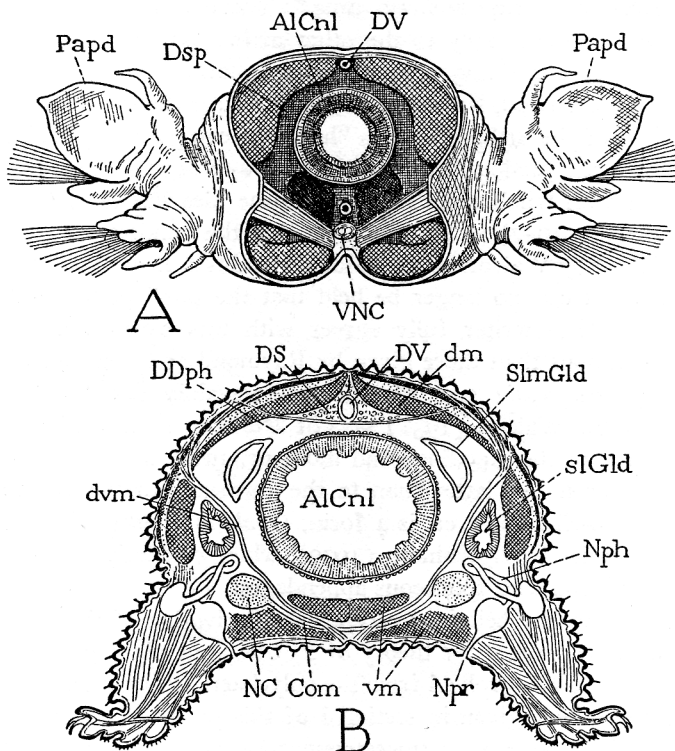


FIG. 26.—Diagrammatic transverse sections of *Nereus* (A) and *Peripatus* (B), showing comparative structure of the appendages of a polychaete annelid and an onychophoran.

AlCnl, alimentary canal; *Com*, nerve commissure; *DDph*, dorsal diaphragm; *dm*, dorsal muscles; *DS*, dorsal sinus; *Dsp*, dissepiment; *DV*, dorsal blood vessel; *dvm*, dorsoventral muscles; *NC*, lateral nerve cord; *Nph*, nephridium; *Npr*, nephropore; *Papd*, parapodium; *SlmGld*, slime gland; *vm*, ventral muscles; *VNC*, ventral nerve cord.

fundamentally metameric animals. The body cavity is undivided by dissepiments, the primitive coelom is represented only by the lumina of the nephridia and the gonads, and the embryogeny of the Onychophora gives the key to the early embryonic development of the arthropods. The onychophoran legs have a lateroventral position on the body (fig. 26 B) as in the arthropods, in contrast to the lateral posi-

tion of the polychaete parapodia (A). The nephridia (B, *Nph*) and the primitive genital ducts open mesad of the leg bases suggestive of their openings on the coxae in many of the arthropods. Though modern Onychophora are terrestrial animals, there can be little doubt that they had aquatic ancestral relatives represented by the Cambrian *Aysheaia* of the Burgess Shale, and perhaps by the Pre-Cambrian *Xenusion* described by Heymons (1928).

The arthropod limbs are developed on the embryo from lateroventral budlike rudiments that lengthen and become segmented. We may therefore suppose that from the ancestral onychophorans (fig. 1 A) a form was evolved with longer legs (B), which later, with sclerotization of the integument, became the jointed appendages of the ancestral arthropods (C). It then required a long period of Pre-Cambrian evolution to produce a trilobite on the one hand, and some ancestral form of crustacean on the other. The differentiation between the two groups, however, was first in the form of the body, not in that of the appendages, as seen in the legs of a trilobite (fig. 25 A) and those of *Marella* and *Burgessia* (B, C). Though there is no valid reason for regarding the primitive arthropod appendage as being a biramous limb, the crustacean appendages later acquired their characteristic biramous structure, which is usually lost in the ambulatory limbs (F).

Many carcinologists hold the view that the phyllopodial type of limb is primitive, at least for the Crustacea, and this concept has been well elucidated by Borradaile (1926a, 1926b). It is supposed that the primitive crustacean appendage was a flat, unsclerotized lobe with a fringe of hairs on the mesal border. Then the inner margin was broken up by the development of a series of endites. Next, the limb became more rigid by a sclerotization of the integument, but this necessitated lines of flexibility that led to a system of jointing, and naturally the joints were formed between the endites. Thus the endites are explained as the precursors of the later developed limb segments. Finally, with the departure from the phyllopodial form and the suppression of the endites, some of the limbs became slender, segmented, leglike appendages. In favor of this theory it may be noted that in many of the branchiopod appendages there are six endites on the mesal margin and a free lobe at the apex (fig. 27 A, B). If all the parts of such a limb became segments there would be seven segments in all, the terminal lobe becoming the dactylopodite, which gives the usual number of limb segments in the Crustacea generally, though Borradaile holds that the maximum number is nine, which would include the doubtful "precoxa" of the trilobite.

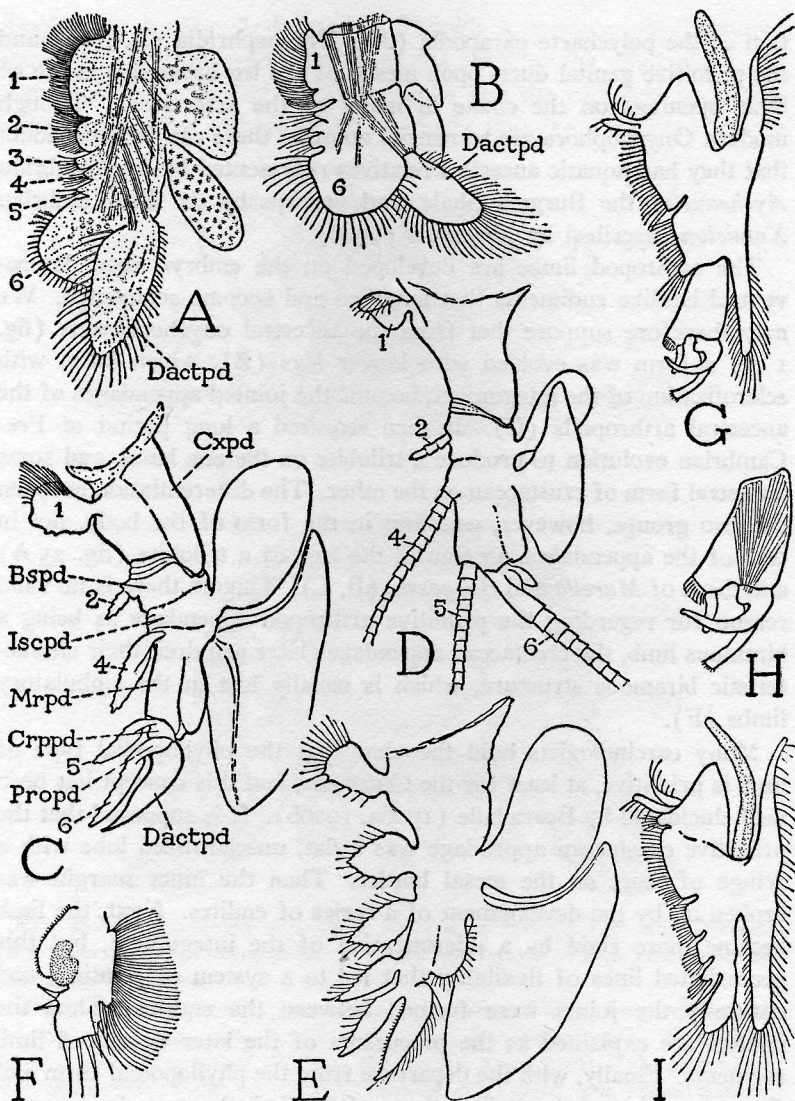


FIG. 27.—Examples of branchiopod appendages.

A, *Branchipus stagnalis*, Anostraca, thoracic limb (from Claus, 1873). B, *Branchipus serratus*, male, eighth thoracic limb. C, *Apus longicaudata*, Notostraca, second maxilliped. D, same, first maxilliped. E, same, thoracic limb from middle of body. F, *Daphnia magna*, Cladocera, third thoracic appendage (from Hansen, 1925). G, *Estheria clarkii*, Conchostraca, second thoracic limb. H, same, terminal segment. I, same, left limb from middle of body.

Bspd, basipodite; *Crppd*, carpopodite; *Cxpd*, coxopodite; *Dactpd*, dactylopedite; *Iscpd*, ischiopodite; *Mrpd*, meropodite; *Propd*, propodite; 1-6, endites.

There are two chief objections to this phyllopod theory of the origin of jointed crustacean limbs. First, it gives no explanation of the origin of the similarly jointed legs of other arthropods, except by the wholly unsupported assumption that they likewise were developed from phyllopodial limbs. Second, the ontogenetic development of the crustacean appendages themselves gives no evidence of a phyllopodial origin, and suggests, on the contrary, that the phyllopodium has been evolved from an ambulatory leg.

The study by Heath (1924) of the postembryonic development of the branchiopod *Branchinecta occidentalis* shows very clearly that the limbs arise as simple, lateroventral lobes of the body segments (fig. 3 B). Instead of taking on a phyllopodial shape, the rudiments grow out first in a slender leglike form (C, D). On the inner margins of the appendages at this stage there are indentations suggestive of an incipient segmentation, and at the apex is a terminal lobe. Only at a later stage (E) do the appendages become broad overlapping flaps. Finally in the adult (F) the appendages have taken on the form of typical unsegmented phyllopodia with three large flat exites, six endites, and a free, independently muscled terminal lobe. Clearly, these appendages in their ontogenetic development undergo a metamorphosis from an ambulatory leg into a phyllopodium. Though Heath himself did not have this phase of the subject in mind, his pictures speak for themselves.

Conversely, as seen in Heegaard's (1953) account of the postembryonic stages of the decapod crustacean *Penaeus setiferus*, the rudiments of the pereopods develop directly into legs without undergoing any stage suggestive of a phyllopodial origin. The pereopods appear during the second protozoal stage as simple lobes on their respective body segments (fig. 28 A). In the third protozoa they take on a biramous structure (B), in which the protopodite, at first undivided, bears a short unsegmented endopodite and a longer exopodite. In the second mysis stage (C) the limbs attain a fully segmented structure by the division of the protopodite into two segments and the endopodite into five, with a terminal chela on each of the first three. The exopodites are now large seta-bearing branches of the basipodites used for swimming. In the postmysis (D) the pereopods have become essentially uniramous by the reduction of the exopodites to small lobes, and the swimming function has been taken over by the pleopods. This condition is retained in the adult. If the pereopods of *Penaeus* had a phyllopodial origin in their phylogeny, there is nothing to suggest it in their ontogeny. The mouth-part appendages proceed along their own lines of development to serve the special functions they have assumed

as organs of feeding. The pleopods (E) and the uropods (F), on the other hand, appear to remain in an early stage of development represented by the simple, unsegmented biramous stage of the pereopods (B).

The swimming appendages of the anostracan branchiopods so regularly have six mesal lobes (figs. 3 F, 27 A, B) and a movable terminal

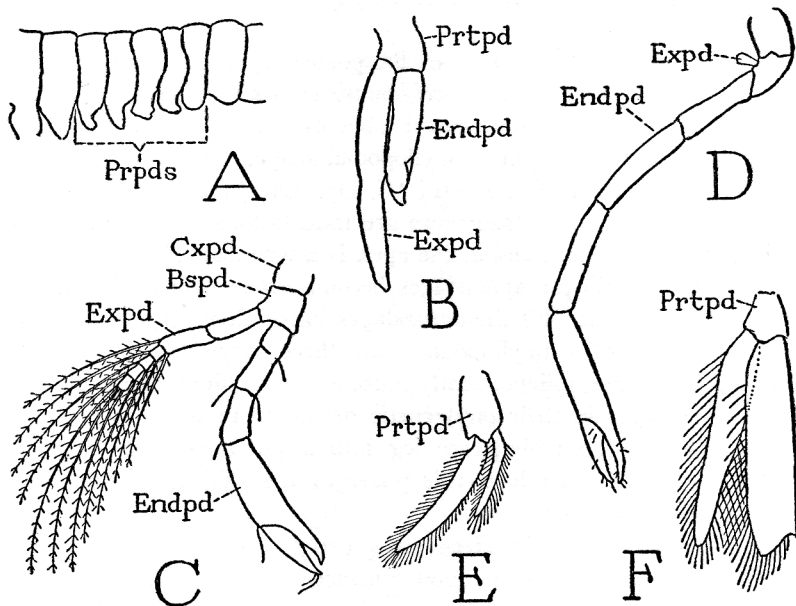


FIG. 28.—Development of the pereopods and pleopods of *Penaeus setiferus* (L.) (from Heegaard, 1953).

A, rudiments of pereopods on thoracic segments of second protozoaea. B, pereopod of third protozoaea. C, pereopod of second mysis instar. D, third pereopod of postmysis. E, second pleopod of young adult. F, uropod of postmysis.

Bspd, basipodite; *Cxpd*, coxopodite; *Endpd*, endopodite; *Expd*, exopodite; *Prpds*, pereopod rudiments; *Prtpd*, protopodite.

lobe as to suggest that the six endites represent the first six segments of a leg (coxopodite to propodite) and the independently muscled apical lobe the dactylopodite. Yet, the sixth endite is commonly interpreted as the endopodite and the apical lobe as the exopodite. In the notostracan *Apus*, however, the second maxilliped (fig. 27 C) is a seven-segmented leg ending with a clawlike dactylopodite (*Dactpd*) and having an endite on each of the other segments except the ischiopodite. The first maxilliped of *Apus* (D) is somewhat simpli-

fied, but the swimming appendages (E) clearly retain the structure of the second maxilliped. In other branchiopods the appendages may be variously reduced (F, G, H, I) obscuring the basic leg structure.

The segmentation of the arthropod legs is surprisingly constant; variations result from the elimination of segments, seldom from addition, though the propodite (tarsus) is generally rendered flexible by subdivision. If all the podomeres in the legs of the trilobite (fig. 25 A) and *Marella* (B) are true muscled segments, the ancient arthropods had eight limb segments, including a small apical dactylopedite, or pretarsus, and thus possessed all the segments that are present in any of the legs of modern arthropods. Among the latter, eight segments are present in the Pycnogonida and in some of the legs of the arachnid Solpugidae (D), but in most of the arachnids the leg has only seven segments by the elimination of the third segment from the base. The segment beyond the knee bend (D, *Pat*), which is the fifth segment in the trilobite leg (A), is called the patella, though it might appear to correspond with the carpopodite (tibia) in the leg of a centipede (E) or a decapod (F). Yet there are three segments beyond it in the spider leg, and only two in the other arthropods. In the latter, therefore, either two original segments in the distal part of the leg are united, or one has been eliminated. The legs of the chilopods and the decapods (E, F) have seven segments; the insect leg has only six segments because of the apparent union of the ischiopodite (second trochanter, or prefemur) with the meropodite (femur).

Though the primitive arthropods (fig. 1 C) undoubtedly were aquatic, they were walking animals provided with jointed limbs, and probably lived on plants in shallow water near the shore. Their habits may have been similar to those of the modern *Anaspides* (D). The typical jointed ambulatory leg has been retained in all modern arthropods, except in those crustaceans in which it has been modified for swimming, but even the phyllopodium preserves evidence of the seven-segmented structure of a walking leg. It would appear that the primitive arthropods had more legs than they needed for walking, and because of this fact their descendants have been able to reconstruct many of them into the great variety of appendicular organs possessed by modern forms. The arthropods owe what they are, as well as their name, to their jointed appendages.

REFERENCES

ALIKUNHI, K. H.

1952. An account of the stomatopod larvae of the Madras plankton. Rec. Indian Mus., vol. 49, pp. 239-319, 25 figs.

- BLISS, DOROTHY E., and WELSH, J. H.
1952. The neurosecretory system of brachyuran Crustacea. *Biol. Bull.*, vol. 103, pp. 157-169, 9 figs.
- BORRADAILE, L. A.
1926a. Notes upon crustacean limbs. *Ann. Mag. Nat. Hist.*, ser. 9, vol. 17, pp. 193-213, 5 pls.
1926b. On the primitive phyllopodium. *Ann. Mag. Nat. Hist.*, ser. 9, vol. 18, pp. 16-18.
- BROOKS, W. K.
1882. *Lucifer*: A study in morphology. *Philos. Trans. Roy. Soc. London*, vol. 173, pp. 57-137, 11 pls.
- CANNON, H. G.
1926. On the feeding mechanism of a freshwater ostracod, *Pionocypris vidua* (O. F. Müller). *Journ. Linn. Soc. London, Zool.*, vol. 36, pp. 325-335, 5 figs., 1 pl.
- CANO, G.
1891. Sviluppo postembrionale dei Cancridae. *Bull. Soc. Ent. Italiana*, vol. 23, pp. 146-158, 2 pls.
- CAPART, A.
1948. Le *Lernaeocera branchialis*. *La Cellule*, vol. 52, pp. 159-212, 22 text figs., 7 pls.
- CAULLERY, M.
1908. Recherches sur les Liriopsidae, Épicarides cryptonisciens parasites des Rhizocéphales. *Mitt. Zool. Stat. Neapel*, vol. 18, pp. 583-643, 8 figs., pl. 26.
- CHURCHILL, E. P.
1942. The zoeal stages of the blue crab, *Callinectes sapidus* Rathbun. *Chesapeake Biol. Lab.*, Publ. No. 49, 25 pp., 4 pls.
- CLAUS, C.
1863. Die freilebenden Copepoden. 230 pp., 37 pls. Leipzig.
1873. Kenntnis des Baues und der Entwicklung von *Branchipus stagnalis* und *Apus cancriformis*. *Abh. Königl. Ges. Wiss. Göttingen*, vol. 18, pp. 1-48, 8 pls.
- DELAGE, Y.
1884. Evolution de la Sacculine (*Sacculina carcini* Thomps.). *Arch. Zool. Exp. Gén.*, sér. 2, vol. 2, pp. 417-736, pls. 22-30.
- DIETRICH, W.
1915. Die Metamorphose der freilebenden Süßwasserkopepoden. I. *Zeitschr. wiss. Zool.*, vol. 113, pp. 252-324, 19 figs.
- DOOCHIN, H. D.
1951. The morphology of *Balanus improvisus* Darwin and *Balanus amphitrite niveus* Darwin during initial attachment and metamorphosis. *Bull. Marine Sci. Gulf and Caribbean*, vol. 1, pp. 15-39, 7 figs.
- ECHALIER, G.
1954. Recherches expérimentales sur le rôle de "l'organe Y" dans la mue de *Carcinus moenas* (L.), Crustacé Décapode. *Compt. Rend. Acad. Sci. Paris*, vol. 238, pp. 523-525.
- FISHER, W. K.
1911. Asteroidea of the North Pacific and adjacent waters. *U.S. Nat. Mus. Bull.* 76, Pt. 1, 419 pp., 122 pls.

FOXON, G. E. H.

1934. Notes on the swimming methods and habits of certain crustacean larvae. Journ. Marine Biol. Assoc. United Kingdom, vol. 19, pp. 829-850, 7 figs.

1936. A note on recapitulation in the larvae of the decapod Crustacea. Ann. Mag. Nat. Hist., ser. 10, vol. 18, pp. 117-123, 4 figs.

FRÄNSEMEIER, LUISE.

1939. Zur Frage der Herkunft des metanauplialen Mesoderms und die Segmentbildung bei *Artemia salina* Leach. Zeitschr. wiss. Zool., vol. 152, pp. 439-472, 17 figs.

GABE, M.

1953. Sur l'existence, chez quelques Crustacés Malacostracés, d'un organe comparable à la glande de la mue des Insectes. Compt. Rend. Acad. Sci. Paris, vol. 237, No. 18, pp. 1111-1113.

GIESBRECHT, W.

1910. Stomatopoden, 1st part. Fauna Flora Golfes Neapel, Monogr. 33, 239 pp., 12 figs., 11 pls.

GURNEY, R.

1924. Decapod larvae. British Antarctic (Terra Nova) Expedition, 1910. Zool., vol. 8, No. 2, pp. 37-202, 78 figs.

1926. Life-history problems of crustacean larvae. *Discovery Reports*, vol. 7, pp. 350-353, 7 figs.

1942. Larvae of decapod Crustacea. 306 pp., 122 figs. Ray Society, London.

1946. Notes on stomatopod larvae. Proc. Zool. Soc. London, vol. 116, pp. 133-175, 14 figs.

HANSEN, J. H.

1925. Studies on Arthropoda. II. Crustacea. 176 pp., 8 pls. Copenhagen.

HEATH, H.

1924. The external development of certain phyllopods. Journ. Morph., vol. 38, pp. 453-483, 5 pls.

HEEGAARD, P.

1947. Contribution to the phylogeny of the arthropods. Copepoda. Skrif. Univ. Zool. Mus., Kjøbenhavn, vol. 8, 236 pp., 27 pls.

1948. Larval stages of *Meganyctiphanes* (Euphausiacea) and some general phylogenetic remarks. Medd. Komm. Danmarks Fiskeri og Havundersøgelser, ser. Plankton, vol. 5, No. 1, 27 pp., 4 pls.

1951. Antarctic parasitic copepods and an ascothoracid cirriped from brittle-stars. Vid. Medd. Dansk Naturh. Foren., vol. 113, pp. 171-190, 7 figs., 2 pls.

1953. Observations on spawning and larval history of the shrimp, *Penaeus setiferus* (L.). Publ. Inst. Marine Sci., vol. 3, pp. 74-105, 133 figs.

HEYMONS, R.

1928. Über Morphologie und verwandtschaftliche Beziehungen des *Xemission auerswalde* Pomp. aus dem Algonkium. Zeitschr. Morph. und Ökol. Tiere, vol. 10, pp. 307-329, 7 figs.

HINTON, H. E.

1946. Concealed phases in the metamorphosis of insects. Nature, vol. 157, pp. 552-553, 1 fig.