CHAPTER III

THE FAMILY ALBUM

EVERY trade and profession has its special vocabulary, and carcinology is no exception. Unfortunately we can not discuss this vast society of little-known creatures without using their names, or at least the names of the large groups into which they are divided. Earlier carcinologists split the class into two subclasses, Malacostraca and Entomostraca, but the latter included such a pageant of diversity that it had to be replaced by four subclasses for the sake of better definition. The classification is now as follows:

CRUSTACEA (Class)

	Subclass	*Series*	*Division*	*Order*
(Entomostraca)	Branchiopoda			Anostraca
				Notostraca
				Conchostraca
				Cladocera
	Ostracoda			Myodocopa
				Podocopa
	Copepoda			Eucopepoda
				Branchiura
	Cirripedia			Thoracica
				Rhizocephala
	Malacostraca	Leptostraca		Nebaliacea
		Eumalacostraca (true Malacostraca)	Syncarida	Anaspidacea
			Peracarida	Mysidacea
				Thermosbaenacea
				Cumacea
				Tanaidacea
				Isopoda
				Amphipoda
			Eucarida	Euphausiacea
				Decapoda
			Hoplocarida	Stomatopoda

The Decapoda, whose guidance we have been following into the physical and psychological mysteries of the Crustacea, belong to the subclass Malacostraca, the great majority of whom, called true or Eumalacostraca, have the grace to keep the number of body segments or true somites at nineteen, a character which makes for ready identification of the membership. All the other subclasses have a number of body segments greater or less than nineteen—never nineteen. And this diversity of segmentation is a symbol of the diversity to be found in all their structural characteristics.

Branchiopoda

The Branchiopoda, first of the subclasses to claim our attention, breathe—so to speak—through their feet. The name means "gill foot." These feet are usually foliaceous or leaflike, divided into a number of lobes, each with a gill plate on the outer side which serves as a respiratory organ like the gills of the higher Crustacea. This peculiarity of "foot breathing" is about the only character common to the four radically different orders that make up the Branchiopoda, though the trunk segments are generally distinct and the trunk limbs alike.

Three of the orders, Anostraca (shell-less), Notostraca (shell-backed), and Conchostraca (mollusk-shelled), are all fresh-water forms. By some these three orders are grouped together under the name phyllopods, in contradistinction to the remaining order—Cladocera. Though they are the only Crustacea that have no known truly marine forms they have no aversion to salty water. One of them is the brine shrimp *Artemia*, the only animal that flourishes in the Great Salt Lake of Utah and similar bodies of water high in salt content. Not only do the adults thrive in these saline waters, but their eggs persist after all the water has evaporated and only salt remains. When the salt is again dissolved, by natural or artificial means, the eggs hatch into a new generation of *Artemia*.

It is recorded that some mud scraped from the bottom of a dried-out salt-water lake of Algiers was carried to France and three years later dissolved in sterilized water, whereupon there hatched out artemias known to inhabit the Algerian seasonal lakes during the rainy season.

Nearly all, if not all, of the phyllopod Crustacea and many other entomostracans—living, as they generally do, in evanescent bodies of water—are endowed in the egg stage with a remarkable drought-resisting faculty. In fact, it is probable that eggs not subjected to some sort of drying fail to hatch—a most providential arrangement; for if it were possible for eggs to hatch without undergoing the apparent vicissitude of a drought, such eggs as remained when the pool became dry—and when the adults, in consequence, died off—might not have the resistance to endure until the next rainy season. Thus the species would be wiped out with the first complete evaporation of its particular little puddle cosmos.

Usually two kinds of eggs are produced by these forms: the so-called summer eggs, purely vegetative and asexual, produced in large numbers and frequently throughout the favorable seasons or periods; and the more resistant dry-season or winter eggs (as the case may be), fewer in number but of greater vitality, and—as a rule, but not always—sexually produced by cross fertilization. In *Limnadia*, among the conchostracan phyllopods, as well as in certain species of ostracods, no males are known or have ever been discovered. Even in the notostracan, *Apus*, males are often of such rare occurrence that their discovery is worthy of note.

The typical anostracan, so-called because of its lack of a carapace, is the fairy shrimp (Fig. 11), of temperate climes. Some fairy shrimps attain a length of an inch or more. The true fairy shrimps are fairies in every sense of the word—graceful and easy of movement, and clothed with delicate draperies (as one might term their many foliaceous limbs), often so beautifully transparent that the shrimps seem almost to be endowed with the fairies' magic cap of invisibility. Such colors as some of them exhibit are largely the result of refraction—evanescent, iridescent greens and blues, which appear at times on some of the appendages

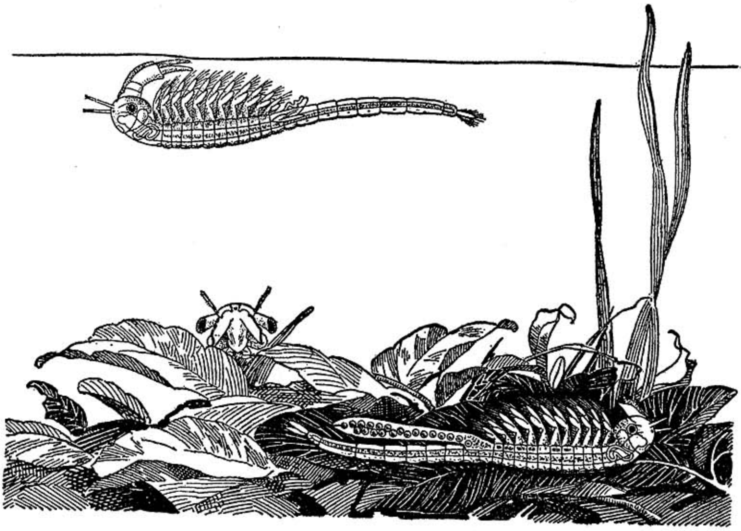


FIG. 11. Fairy shrimps (*Branchinecta paludosa*) in a pond. Female with egg sac among leaves; male swimming and feeding at the surface in normal inverted position

over a ground of translucent creamy white with reddish trimming. Though common in many parts of the world, fairy shrimps are seldom seen except when especially sought after. Their occurrence, too, seems largely subject to all the vagaries of *Apus*, recounted below.

Apus (Fig. 12), which belongs to the order Notostraca, a name that refers to the shell-like carapace of its members, looks remarkably like a small horseshoe crab. It is the giant of all branchiopods and may measure nearly three inches in length. Contrast this with the one hundred and twenty-seventh of an inch, which *Allonella*, one of the Cladocera, measures when full grown. The chief claim of *Apus*, however, to popular attention is its in-

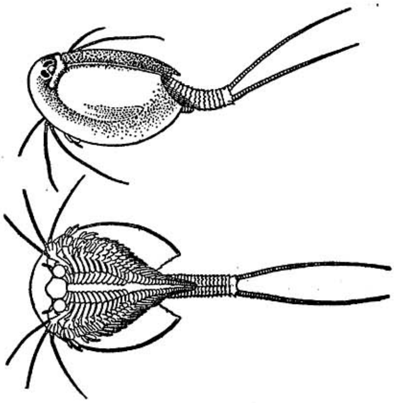


FIG. 12. *Apus* giant among the branchiopods. Lateral and ventral views. Adapted from Sars

constancy of habitat. Though not uncommon from year to year on the continent of Europe it makes some very curious skips and jumps in its seasonal appearance, and one can not definitely count on finding it in the same locality two years in succession. Frequently it fails to appear in a given area for a number of years; and once a period of fifty-seven years elapsed from its recorded occurrence in Great Britain in 1850, as published by Baird, to its reappearance in the southwest corner of Scotland in 1907. That, furthermore, is the only rediscovery of it in Britain from that day to this. This sporadic occurrence keeps *Apus* from becoming the economically valuable form that its individual bulk and great numbers would otherwise make it. What accounts for this curious phenomenon, no one knows.

The third phyllopod order, the Conchostraca (Fig. 13), gets its name from the development of the carapace of its members into a bivalve shell, completely inclosing the body and limbs and closely resembling the shell of a

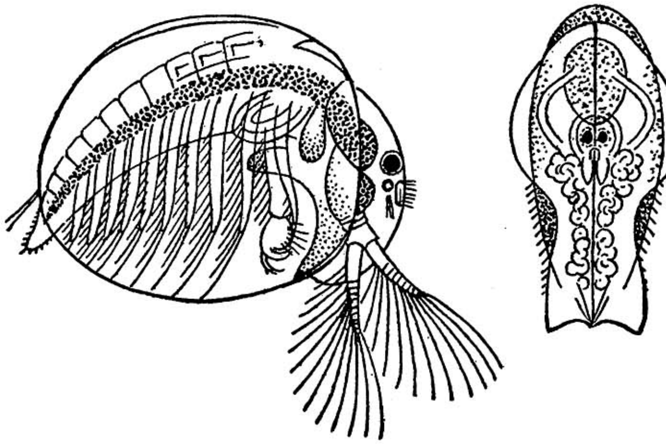


FIG. 13. Branchiopod (*Limnetis*) with a bivalve carapace. Lateral view of female and frontal view of male (x 10). After Sars

small mollusk. A similar development has taken place in most of the Cladocera, although in these Crustaceans the head is left free.

"Water-fleas" the Cladocera are named, from their jumping mode of progression. They have none of the erratic characteristics of the phyllopod *Apus*, and though of very small size, even microscopic, they occur in such great numbers that they furnish the basic food supply to many of the commercial fishes of the Great Lakes. Indeed some species of Cladocera are marine and form such considerable swarms at sea that they must contribute largely to the food of salt-water fishes likewise, though here they give precedence to members of the subclass Copepoda.

Daphnia pulex, one of the best known cladocerans, bears in her specific name the brand of her resemblance to the flea. Her diminutive size hides much delicate beauty from our gross vision. Under the microscope she can teach us a great deal about the reproductive habits of the branchiopods. Something has been said of the two sorts of eggs laid by members of the preceding subclasses. *Daphnia*, in common with the other cladocerans, carries her eggs around in a brood pouch inclosed by the dorsal part of the valves of her carapace (Fig. 14). Here

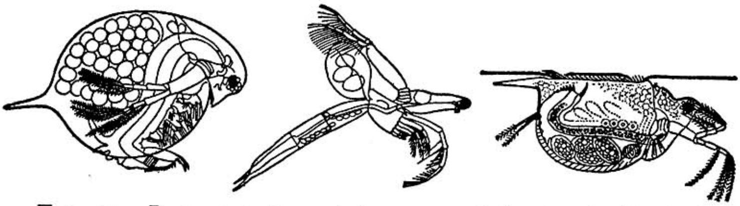


FIG. 14. Representative cladocerans. Left, female *Daphnia pulex* (x 6). Center, female *Leptodora kindtii* (x 1½). Right, female *Scapholeberis mucronata* (x 20), using surface film of water as a support. After Keilhack, Pearse, and Scourfield

is the nursery in which the eggs develop and where the young hatch out in a form not unlike the parent and are sheltered till fairly well grown before being sent out to seek their own livelihood. Thus it is that we find no free-swimming larval forms among the Cladocera. The offspring are nourished in quite a remarkable manner. For the long period of their sheltered existence, the egg yolk with which they hatched into the world would not alone suffice, so as they grow up they feed, also, upon a secretion from the walls of the brood chamber.

This is the course of the parthenogenetic young, which consist usually of several successive generations of females. But sooner or later, with the approach of unfavorable conditions, such as winter or the drying up of the body of water in which they live, true sexual males and females hatch out. These in turn unite to produce fewer (usually one or two) but larger eggs, heavy with much yolk and with a thick, resistant shell. Like the other eggs, these, too, pass into the brood-chamber, which now becomes more or less modified and thickened. In *Daphnia*, particularly, this transformation becomes quite marked; the valves of the carapace take on a peculiar shape like a saddle; and so the carapace in this genus bears the technical name of ephippium derived through the Latin from two Greek words meaning "on a horse." The purpose of this modification is seen in the next molt, when the ephippium becomes detached from the rest of the shell and closes snugly about the eggs it is to guard, thus protecting them until the next favorable season.

These winter eggs, like those of other lower Crustacea, are very drought resistant. Mud taken from the dried-up Pool of Gihon, at Jerusalem—a pool whose history goes back some twenty-five hundred years—was moistened, and there hatched out not less than seven species of Crustacea, of which at least two were new to science at the time. One bit of mud from this pool was alternately moistened and dried out in the laboratory year after year for twenty-four years, thus simulating the wet and dry seasons of its normal environment; and each year until an accident terminated the experiment, new Crustacea hatched out. Other portions of this dry mud were laid away for nine and ten years and then moistened, whereupon Crustacea hatched out.

Of the Cladocera, only a few are not "shelled." The carapace of shell-less forms is transformed into a distinct and conspicuous brood pouch. These aberrant members of the order present such radical departures from the usual cladoceran form that they constitute a group apart, in which is included *Leptodora kindtii* (Fig. 14), without doubt the largest cladoceran, the female reaching a length of nearly three-quarters of an inch. Any other species, when full grown, is of good size if it measures as much as a sixteenth of an inch from head to tail.

Some cladocerans have adjusted themselves to a life in the mud, and the shells of these are often overgrown with algae. But adaptations of an extraordinary nature have been developed by the species that lead a swimming existence to enable them to minimize the energy expended in keeping afloat. A few, including *Scapholeberis* (Fig. 14), hold themselves to the surface of the water by making fast to the surface film. For this purpose they possess specially modified, water-repellant scales and setae on their ventral surfaces. Swimming in their normal position, back downwards, they pierce the surface film and hang thus, drifting about, foraging along the surface of the water at will or releasing their hold to dive readily to the bottom. Swimming ventral side up seems to be the normal method in many, if not most, of the caldoceran and phyllopod crustaceans.

Advantageous as the surface film is to *Scapholeberis*, it is deadly to numerous other less well adapted Entomostraca, including *Daphnia*. If one of this genus happens to break through the surface film, it is almost as serious in its consequences as for a man to fall out of a third-story window; for upon penetrating the film it tends to fall over on its side, perfectly helpless in the powerful and relentless grip of the surface tension of the water. This is the same force that enables a steel needle to float in a glass of water. The only escape for *Daphnia* from such a hopeless condition lies in the release that a violent disturbance of the water might afford, unless the animal happens to be about to molt. In such a happy chance, like the thief that escapes by leaving his coat in his pursuer's hands, she is able to slip out of the old shell or chitinous housing, which remains floating at the surface of the water, while, newly molted, she regains the safe, cool depths. Helpless individuals of this genus have been observed at times in such numbers that they formed a scum upon the surface of the water, many square yards in area.

CRUSTACEANS

Ostracoda

Abundant in all seas and lakes and in almost all bodies of water, down to the merest roadside puddle, the Ostracoda (Fig. 15) probably stand next to the Copepoda among Crustacea in their importance to zoological economy. They

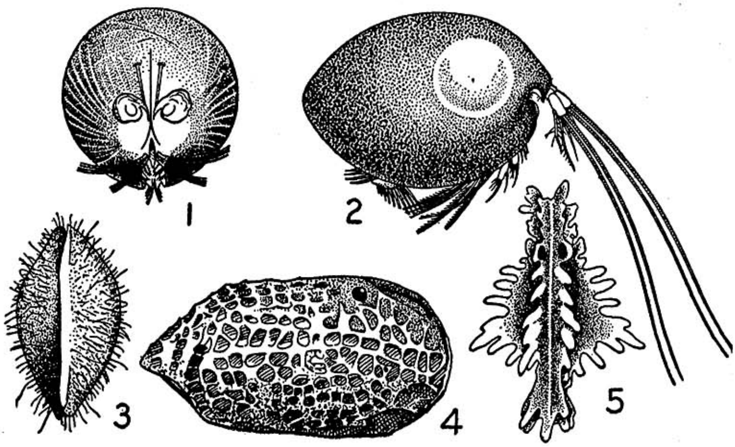


Fig. 15. Representative ostracods. 1, frontal view of a female *Gigantocypris*, largest of the ostracods (natural size); 2–5, other species (much enlarged.) After Müller

often occur in such teeming numbers as to lend color to the water. Some of them inhabit great altitudes, one species (*Cypris altissima*) having been found in a pool fed by melting snow 12,000 feet above sea level.

The great depths of the ocean have yielded the largest known ostracod. This is appropriately labeled *Gigantocypris*; for it is nearly an inch in length, which makes it a giant indeed as compared to some of the really small forms which measure only a hundredth of an inch over all.

Among Crustacea the Ostracoda are remarkable for the small number of their appendages and their unsegmented or, at best, very indistinctly segmented body, inclosed in a bivalve shell fashioned from the carapace.

Few other crustaceans are so completely encompassed by their housings. So much do they resemble small mollusks that frequently we are asked to identify the tiny "shells" this or that correspondent has unexpectedly found in some body of water.

But few as the ostracod's appendages may be, they are very powerfully developed and fulfill all the essential functions performed by the more generous number with which other crustaceans are endowed. Ostracods depend on the first and second pairs of antennae for a variety of services. In some forms these are the only appendages that protrude from the shell. Aside from their sensory function, they are the locomotive organs, and most efficient ones at that, whether the mode of progression be swimming, creeping, or burrowing.

Of the food and feeding of ostracods there is still ever so much to be learned. The more closely observed fresh-water forms seem to be omnivorous, subsisting upon almost anything that comes to hand, living or dead, animal or vegetable. Marine forms, though more difficult to observe, seem to feed largely on diatoms and other plants of the sea and shore. Carnivorous tendencies crop up in some of them; but all in all, by mere press of numbers, they must play an enormously important role as scavengers and as intermediates in the conversion of food material into a shape utilizable by larger animals. Certain species suck the juices of marine plants, for which purpose their upper and lower lips are organized, with the jaws, into a peculiar sucking proboscis. Incidentally, the ostracods that parasitize other animals have a similar adaptation. Only a few such parasitic ostracods are known, one having been taken from a fish, a second from a sea-lily, and two others from different crustaceans.

Some marine ostracods have been found with the remains of copepods in their alimentary tract. These species have taken a leaf from the birdlimer's book and ensnare their prey by means of a sticky secretion spread over the fore part of the shell. Here any copepod that comes in contact with it is held fast, much as flypaper holds a fly. The glands of ostracods and their secretions are quite a study in themselves. Certain genera—*Pyrocypris* and *Cypridina*—are even luminous, thanks to a phosphorescent secretion which they can expel in clouds and so possibly foil a pursuing enemy. In others the fluid expressed from the glands serves to agglutinate the sand in which the ostracods burrow, and so provide their builders with definite tubular retreats. Others have a spinning gland, from which issues a sticky substance that quickly hardens and forms a thread. With this the ostracod, after the manner of familiar spiders, weaves a network to secure himself to his immediate surroundings or to enable him to climb about where otherwise his foothold would be precarious.

In common with a number of other Entomostraca, many ostracods reproduce parthenogenetically; that is, the females bear eggs which are capable of hatching and producing the succeeding generation of ostracods without the intervention of a male. Under experimental conditions in an aquarium, successive generations of females have been kept going for as long as eight years in one stretch. In fact, males of some ostracod species have never been found. Like our branchiopod water-flea, ostracod mothers may carry the eggs and sometimes even the young. Often the eggs are deposited on seaweeds, or merely shed into the water.

In vitality, also, the eggs of ostracods share honors with those of other fresh-water entomostracans, remaining viable in dried mud for years. G. O. Sars, of Norway, one of the foremost students of Entomostraca of all time, made a practice of soliciting bits of puddle, pond, and ditch bottom from all parts of the world. He was thus able to hatch and describe no end of new and unusual species of ostracods without the expense entailed by special expeditions in search of them.

But ostracods are unique in that even some of the adult forms, in spite of extreme dessication, may be brought back to a condition approaching normal by soaking them in water, though they may never actually come to life, as do the eggs on hatching. In the charming words of T. R. R. Stebbing, "Their delicate little corpses dry up within their own organic sarcophagus, and need no embalming to make them inoffensive. They remind one of that romantic country in which the old men never died but only shrivelled, and could, by process of steeping in hot water, be occasionally revivified to answer the enquiries of a younger generation."

Copepoda

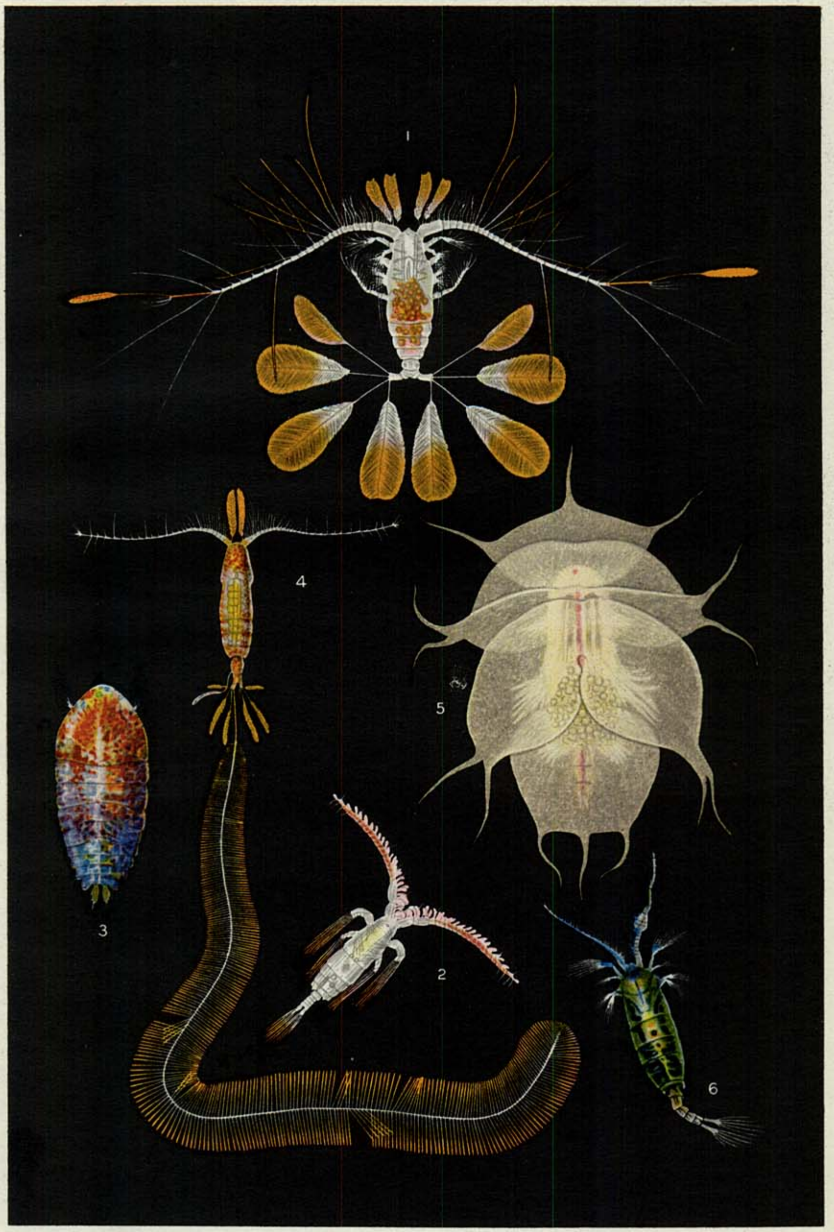
Some of the mighty whalebone whales—among the world's largest mammals—and fish fry so small as to be microscopic are alike beholden for their existence to copepods, the oar-footed crustaceans. More fish and other aquatic creatures feed on these tiny crustaceans than on any other one kind of animals known. The copepods, in the main, form the base of the pyramid of marine life, transforming, as do the ostracods, the microscopic vegetable life of the sea and inland waters into food which can be utilized by animals larger than themselves. In the sea the copepods have no rival as food for fishes, and even in the Great Lakes they run the cladocerans a close second. The copepods are therefore of more than mere academic significance to man. There is a phrase current in certain parts of Europe that herring is king; but "King Herring" feeds upon copepods, and no copepods, no herring.

Of the hundred million pounds of fish caught annually in the Great Lakes, whitefish and lake herring form the bulk; and cladocerans and copepods constitute from sixty-three to ninety-seven per cent by volume of the food of these two kinds of fish. Like the cladocerans and the ostracods the copepods compensate for their microscopic size by their unbelievably large numbers. They multiply more rapidly than the proverbial flies. A rough estimate of the number of individuals produced annually in a mere ten cubic meters of Baltic sea water is nine billion.

But not all copepods are the helpless victims of the appetites of other organisms. The race has predatory capacities of its own and has, moreover, made parasitism a fine art. It has displayed a genius for adapting itself to live at the expense of practically every other living thing in the sea. Any scheme of classifying copepods divides them naturally, therefore, into free-swimming and parasitic forms.

The free-swimming copepods differ from their parasitic relations as good differs from evil. James Dwight Dana, famous not only as a geologist but as a zoologist as well, described not less than twenty species of the genus *Sapphirina* (a name derived from the Latin word for sapphire), endowing each with a name—also in Latin—appropriate to its most obvious character, such as "the beautiful," "the metallic," "the variegated," "the splendent," "the scintillating," "the rainbow," "the opalescent," and so on. "Nothing," he says, "can exceed the beauty of some species, and especially the males." (Plate 39, No. 3.)

Along with color go the most bizarre shapes and bodily adornments resulting from adaptations to make flotation easy. Many free-swimming copepods are active forms, others are more or less passive floaters (with the means for such an existence), while still others are jumpers and skippers. Some of the latter are so energetic and occur in such immense numbers that they give the most startling illusion of rain at sea, although there may not be a cloud in sight above the horizon. In particular I have reference to *Anomalocera pattersoni*, a form that lives close to the surface of the sea and for which "flying fish of the copepod world" would not be an inappropriate designation. The Norwegian fishermen call them "Bla-ate" (blue bait) and hail a "shower" of them as a good sign of the approach of



Copepods: 1 and 2, *Calocalanus pavo*, female and male respectively; 3, *Sapphirina ovatolanceolata*, male; 4, *Calocalanus plumulosus*, female; 5, *Notopterophorus elatus*, female; 6, *Anomalocera patersonii*, male. Much enlarged. After Giesbrecht

the summer herring, which feeds upon them in vast numbers. Among the floating Copepoda are some of the most notable members of this subclass, long to be remembered for their splendor of form.

Pelagic copepods may first attract our attention, but they have hundreds of bottom-dwelling relatives. Even

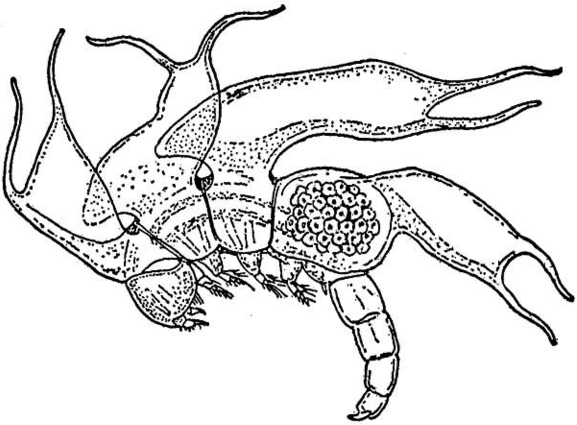
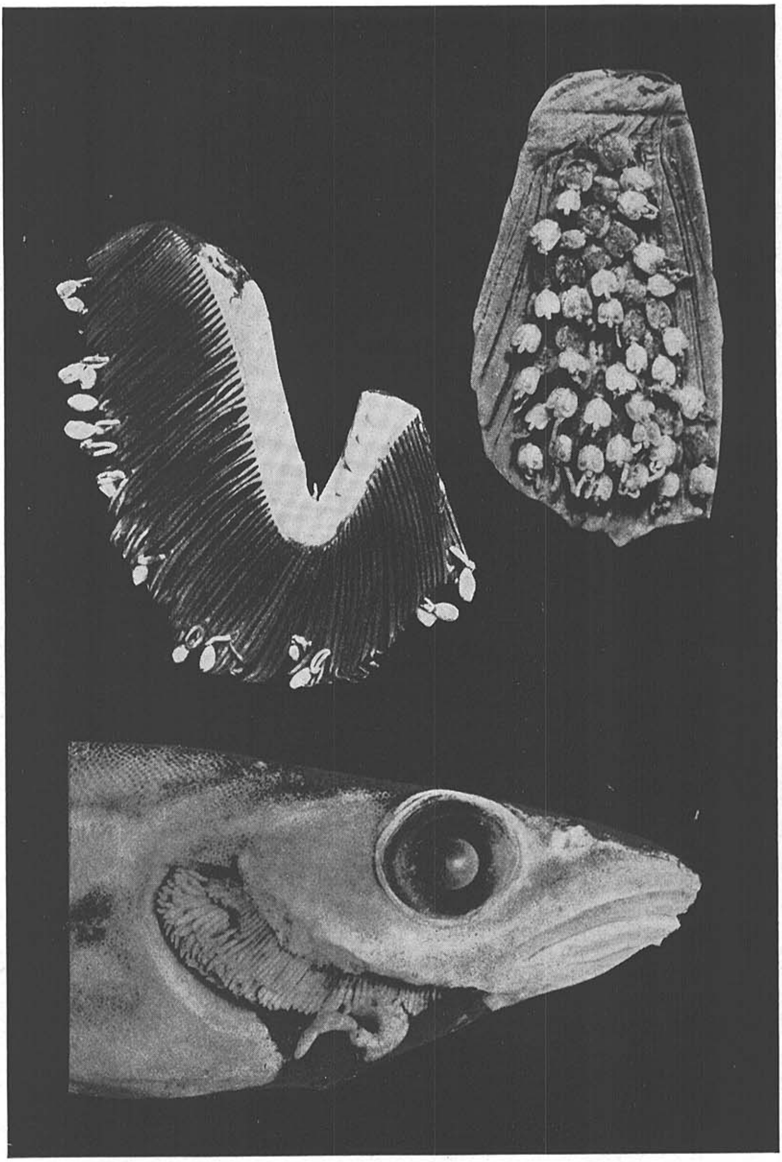


FIG. 16. A female butterfly copepod (*Notopterophorus papilio*) with eggs (x 15). Compare with Plate 39, No. 5, which is the dorsal view of a related species. After Sars

the hard-packed sandy beaches of our shores support a considerable copepod population. In a single pail of sandy water taken from a New England shore Prof. C. B. Wilson gathered 800 specimens belonging to twenty-five species of Copepoda, several of which were new to science. Marine copepods, also, occur in the abysses of the ocean at depths of 2,650 fathoms—three miles below the surface.

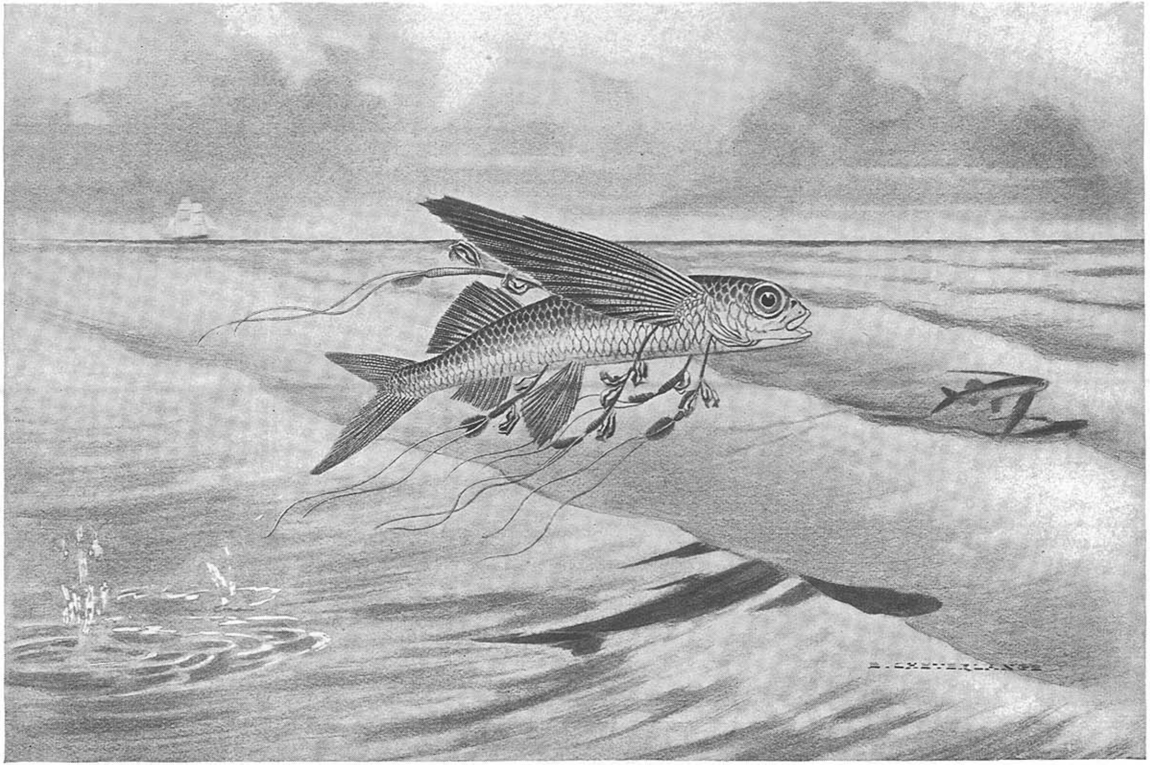
Of the widespread fresh-water copepods the best-known genus is *Cyclops*, so named because, like all typical copepods, it has but a single median eye in the middle of its forehead. The running water of streams seems to be more scantily populated with copepods than that of pools or lakes. Fresh-water copepods share the common name of water-fleas with the cladocerans, the smaller phyllopods, and the ostracods; also they share with the three latter forms their varied and unusual habitats the world over. The fresh-water copepods are perennial, like weeds in the field. Some species are strictly summer forms, and others seem to thrive best in the colder parts of the year. Some cold-water copepods, like *Cyclops bicuspidatus*, are said to spend the summer months in cocoons formed of mud and other bottom materials held together by a glutinous secretion. Because of their occurrence in vast numbers in favorable situations, these fresh-water copepods, like their marine relatives, constitute a very important item in the diet of many fresh-water fish, and probably in that of the young or larval stages of most of them.

Turning to the amazing story of the parasitic copepods, we learn—as the result of Professor Wilson's extensive studies of them—that in no other group of Crustacea has parasitism led to such diversity of structure and life history. The parasitic habit of life has been adopted to a greater or less degree by many different families in the group, and every step in the transition from the more normal free-swimming type to a completely parasitic one is represented. There is scarcely a class of animals that is not adversely affected by one copepod or another, unless it be the microscopic unicellular Protozoa, which are even smaller than the smallest copepod and hence too small to support the luxury of a crustacean parasite. The modifications of structure which parasitism has effected in some species of Copepoda are so great that no one could be expected to guess their crustacean relationship. But by their larvae you shall know them; for like all good entomostracans, no matter what their later life may be, most of them leave the egg as a minute nauplius. (Fig. 17.) Normally following the nauplius and metanauplius forms (of which there may be several stages) the larva transforms into the copepodid stage, which is a precursor of the final adult



Parasitic copepods on fishes

Upper left: *Lernaeopoda* on gill of salmon. Upper right: Thirty-two individuals of *Lepeophtheirus* on fin of flounder. Lower: *Lernaeocera* on gill of whiting. After Scott. Courtesy of the Ray Society, London



Copepods (*Pennella exocoeti*) and barnacles (*Conchoderma virgatum*) parasitic on a flying fish stage. Some of the parasitic forms pass through the nauplius stages while still within the egg and hatch as a free-swimming copepodid. At this stage, the tiny animal seeks a host to which to attach itself, subsequently under-

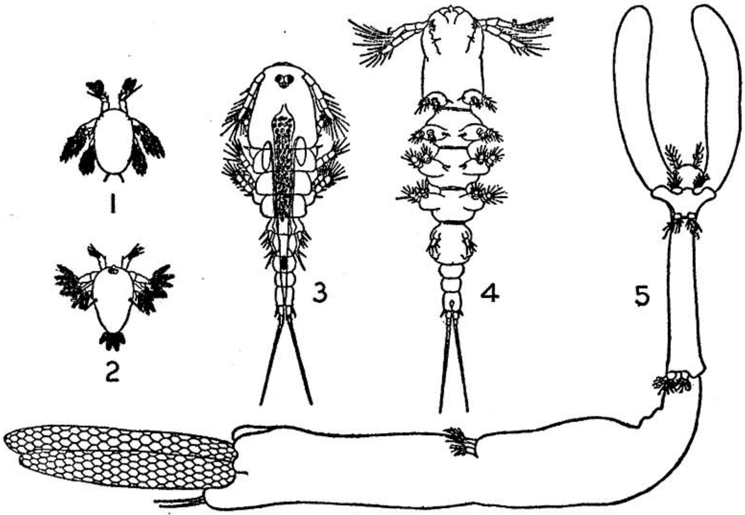


FIG. 17. Stages in the development of the parasitic copepod *Lernaea variabilis*. 1, nauplius (x 40); 2, metanauplius (x 40); 3, female fourth copepodid larva (x 35); 4, male fourth copepodid larva (x 40); 5, adult female (x 10). After Wilson

going transformation into a rather strange adult—usually little more than a feeding, reproductive mechanism for producing further parasitic copepods.

The most familiar, by name at least, of the parasitic copepods are the fish-lice, though this term is equally applicable to certain parasitic malacostracans quite far removed, carcinologically speaking, from the entomostracan fish-lice before us. One of the more thoroughly investigated genera, *Lernaea*, of not uncommon occurrence on certain tropical and temperate fresh-water fishes, will illustrate the life history of the group. The free-swimming copepodid larvae attach themselves to the gills of a convenient fish host of the right species, and there male and female mate while still in a larval stage. Thereupon the male, his usefulness at an end, apparently dies, like the drone of the beehive. The female, on the other hand, deserts her first fish host to settle down on a second host, this time on the outside of its body instead of on the gills. Once established she becomes transformed into the adult, as we know her, of the species she represents, and becomes a permanent, fixed parasite for the rest of her natural life. For purposes of secure attachment, the sides of the cephalothorax grow out laterally as "horns," which may extend into the flesh of the host or else become firmly affixed to its scales; in either case, however, the head burrows in the tissues of the host in search of nutriment. This treatment often causes a good-sized lump or tumorous growth to develop on the host, and this may be raw and bleeding within. It has a perforation through which the hinder part of the parasite projects in order that her young shall have no difficulty in taking up a free-swimming existence when once the fertilized eggs begin to hatch. Considering that *Lernaea* is a pronounced parasite, the free-swimming larvae of the genus are exceedingly active and very tenacious of life. They are for all the world like any other entomostracan in their structure and behavior at this time of life, exhibiting characteristics which we have learned to associate with the two preceding subclasses of Entomostraca—the Ostracoda and the Branchiopoda.

All families and, in fact, all species of fishes seem to be victimized by one or another of the parasitic copepods, and a list of the hosts of the copepods in a given body of water is well nigh a catalogue of its fish population. And the poor fishes are attacked in every conceivable manner and in almost every conceivable part of their anatomy—in the mouth cavity, on the gills, and even in the nostrils, as well as within the body.

The spiracle of the gray skate harbors *Charopinus*, a fellow full two inches long. The nostrils of the cod are the chosen home of another copepod, which evidently feeds on the mucus secreted there. As many as twenty-nine individuals have been taken from the nostrils of one cod. To still other genera the eyes of their hosts offer the one worth-while abode, and they become so embedded in these organs that only the most painstaking dissection can remove them entirely. One of these—*Phrixocephalus diversus* Wilson—burrows completely through the fish's eyeball, halting only when its head again emerges on the side opposite to that on which it entered; there it invests the outer wall of the retina with its mouth so as to draw on the rich blood supply of the network of vessels nourishing the retina. Of course, the sight in the organ attacked is forever doomed. Other species of copepods burrow into the body cavity of the host and attack the heart, liver, and other vital organs.

The largest and the most striking of the copepods, genus *Pennella*, are found as parasites on at least eight genera of fish, including the giant swordfish, the shark sucker, the gigantic ocean sunfish, and the flying fish (Plate 41). As can be seen in Figure 18, the abdomen of *Pennella* carries a series of branched featherlike processes arranged in a row on either side. These so resemble feathers in appearance that not only do they give the genus its name, for *Pennella* is the diminutive of the Latin *penna*, a feather, but the species infesting flying fish are popularly known as the "feathers" of this soaring inhabitant of the tropic seas.

Pennella, as well as some other parasitic copepods, victimizes other animals besides fish. *Pennella balaenopterae* is found in considerable numbers on the common rorqual or finner whale—one of the largest of mammals. This species may attain a length of twelve and a half inches not including the ovisacs or egg strings, which sometimes trail out behind the body of the parasite for a distance as great again. The possession of egg strings or egg sacs, incidentally, is very often a distinctive copepod character, whether the form be marine or fresh-water, free-swimming or parasitic.

On the whale, too, is found another copepod, whose parasitism—if its habit of life can be so designated—might be difficult to demonstrate. *Balaenophilus unisetus*, in all its stages from the newly hatched nauplius to the adult form, clings in such numbers to the baleen or whalebone plates of its host as to form great yellowish patches on them. Quite unlike the free-swimming nauplii usual to other copepods, those of *Balaenophilus* are sedentary, probably with very good reason; for if a baleen-infesting copepod were free-swimming it might unwittingly leave "home and fireside"—a move tantamount to losing itself in the wide-open spaces of the high seas, since the number of baleen whales is comparatively small and since these desirable hosts cruise through a vast expanse of water at the rate, often, of twenty miles an hour. A lost or strayed copepod, therefore, would have a poor chance of finding another suitable host. And not only is the nauplius of this copepod sedentary, but the species at all stages is equipped with powerful grasping organs, which enable it to keep its place on the whalebone plates and to resist the strong current of water that must pass between the plates when the whale is in the act of straining his food. The adult female of this species may reach a length of 2.4 millimeters, while the male is somewhat smaller. To this day the only specimens of *Balaenophilus* known to science are the original lot taken in 1879 by Dr. Carl Aurivillius, the Swedish naturalist, from the baleen of the sulphur-bottom whale.

It would seem that animals that spend but a part of their lives in water are as helpless as the deep-sea dwellers to escape these widely distributed and marvelously adapted copepod pests, for in Japan the genus *Lernaea* has been found on an amphibian, the Japanese salamander. This is the only vertebrate other than fish and marine mammals known to be infested with parastic copepods.

There is no conception of *noblesse oblige* among the Copepoda and they willingly levy tribute on any convenient crustacean relative. Even the land crab of the West Indies, the big bluish-gray *Cardisoma guanhumi*, which but once a year goes down to the sea to hatch its young, supports two known species of parasitic copepods on its gills; and as many as thirty copepods have been obtained from the gills of a single crab host. These parasites, of necessity, must have their lives so beautifully attuned to that of the host that they, too, can take advantage of the crab's annual dip in the ocean to perpetuate their own kind, which will in turn infest other land crabs as they are spawning. Since this dip endures but ten days at the most, the adjustment is a most remarkable provision of nature. There can be no doubt that it exists, however; for though the crab's gill, while that animal is on the land, is moist enough to keep the copepod alive, it does not appear to be moist enough to aerate the copepod's eggs properly.

Copepods of the family Choniostomatidae are found parasitic on other crustaceans exclusively. One might call them microscopic nits. They bore a little hole in the shell of the host to obtain sustenance; and the female, at least, spends the balance of her life in complete dependence. Shrimps of several kinds, mysids, and especially amphipods, isopods, and cumaceans are all attacked by these tiny beggars.

The starfishes and their kind, collectively known as echinoderms, likewise contribute to the support of parasitic copepods. Four species of these crustaceans have been taken from three different kinds of ophiurans, as the brittle stars are technically termed. The parasites often establish themselves within the host and usually produce malformations or galls.

Parasitic copepods also prey on hard-shelled mollusks. While still in the nauplius stage they find their way into the gill tubes of the sand clam *Mya;* and they are found in two species of mussels, in the toothsome scallops, in razor clams, and in cockle shells. *Pennella* larvae have been found on the gills of the cuttlefish—a mollusk with an internal shell; nor have the nudibranchs—sluglike mollusks without shells—escaped giving food and shelter to uninvited copepod guests.

Degeneration or specialization among parasitic copepods is carried to the extreme in those forms that live on certain marine annelid worms and also in those that live on certain other crustaceans. In the best known of these highly specialized forms the adult female is entirely without appendages and is attached by a tubular process which ramifies within the body of the host. The males are also limbless; and, rather remarkably, they never escape the last larval stage—in this case the first copepodid stage—spending their lives attached to the female of their species (several males to each female).

Of the other lesser known animals of the sea, those commonly parasitized by copepods are the jellyfish and the soft corals (sea pens and other alcyonarians). Temporary- or semi-parasitic copepod forms have been found on sponges, also. And one strange species seems to live in and prey upon a marine plant, causing a gall-like malformation on its fronds.

We have spoken of the magnificently colored free-swimming males of the genus *Sapphirina*. The wives of these gallant cavaliers are generally quite colorless creatures which devote a considerable part of their lives to raising one brood after another within the "glass houses" of the salps which they parasitize.

The more one delves into the relations of animals to one another, the more often one finds illustrated Dean Swift's oft misquoted doggerel:

> So Nat'ralists observe, a Flea
> Hath smaller Fleas that on him prey.
> And these have smaller Fleas to bite 'em,
> And so proceed *ad infinitum*.

Copepods are no exception. *Pennella*, which parasitizes the whale, is, in turn, the unwilling support of a peculiar barnacle, *Conchoderma virgatum*. The barnacle in this case is a passive parasite, making use of but not actually subsisting on its host. It merely adds to the sum total of the

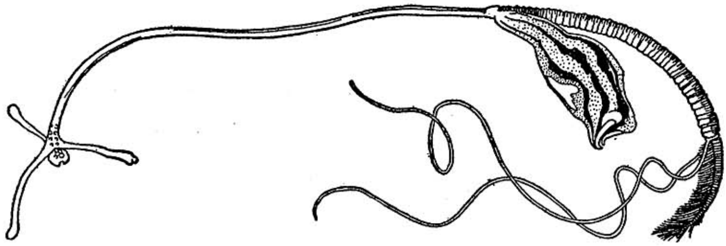


FIG. 18. A parasitic copepod (*Pennella balaenopterae*) taken from a finner whale, and itself carrying the barnacle *Conchoderma*. After Turner

burdens which the copepod is called upon to carry through its marine existence. Dr. C. B. Wilson tells of a *Pennella* four inches in length to which were attached eighteen *Conchoderma*, the latter forming a mass many times the size of the copepod. Dr. Wilson remarks that the *Pennella* exemplify the fact that one parasite often serves as the host for another. Attached to the outside of their host, where they catch all that floats in the water, the *Pennella* very quickly become covered with algae, ciliate infusoria, hydroids, and even barnacles, as noted above. Seaweeds, too, find their place on these copepod parasites. Though troublesome to the parasite on account of their weight and bulk, these added organisms are not to be considered superparasites, for they do not feed on the copepods to which they attach themselves.

The most remarkable case of multiple parasitism is one reported by Dr. C. Perez. A Mediterranean bivalve, *Spondylus*, like many of its kind, often harbors a pinnotherid crab, parasitic to the extent, at least, of feeding on the foodstuffs collected by the bivalve for its own consumption. Dr. Perez found one of these crabs that was itself infested with a rhizocephalid (of barnacle kinship), and the rhizocephalid in its turn was being preyed upon by an ectoparasitic isopod of the genus *Eumetor*. Isopods on the rhizocephalid *Sacculina* as secondary parasites have been noted before; but a tertiary parasitic relation of the sort just recounted is quite unusual, though not unreasonable.

But *Sacculina purpurea* presents a much more astounding phenomenon. This rhizocephalid is not uncommon as a parasite on a certain South American hermit crab; and its roots are made use of by other parasites, which, to quote Stebbing, "take up their abode beneath the *Sacculina* and cause it to die away by intercepting the nourishment conveyed by its roots; and when the *Sacculina* itself is dead its roots continue to flourish and abound at the expense of the hermit and for the benefit of the besieging *Bopyrus* [a genus of the parasitic isopods]."

In all this gamut of parasites there is still one more group of copepods, or, rather, "near-copepods" to be mentioned. These are the "fish-lice" in the true sense of the term, and in the form of the genus *Argulus* (Fig. 19), they have been met with on frequent occasions in goldfish aquariums. The argulids differ from all true copepods in possessing paired compound eyes. They feed on the blood of their host, and those that infest migratory fish are strongly suspected of being able to change with their host from salt to fresh water or the reverse. Another peculiarity of the argulids is that they do not carry their eggs around with them, as do regular copepods, but deposit them on some favorable surface on the bottom, or, if in aquariums, sometimes on the glass sides. If an argulid does not succeed in finding a host of the species on which it is specifically parasitic, it has been known to live on almost any other fish, and even on tadpoles. Naturally, a change is made to its natural host at the first opportunity. Rather wonderful, this sense of host recognition among animals of this low degree, whatever its explanation may be.

The argulids are ready swimmers, but progress rather peculiarly—by somersaulting through the water, as it were. An external parasite needs an efficient means of

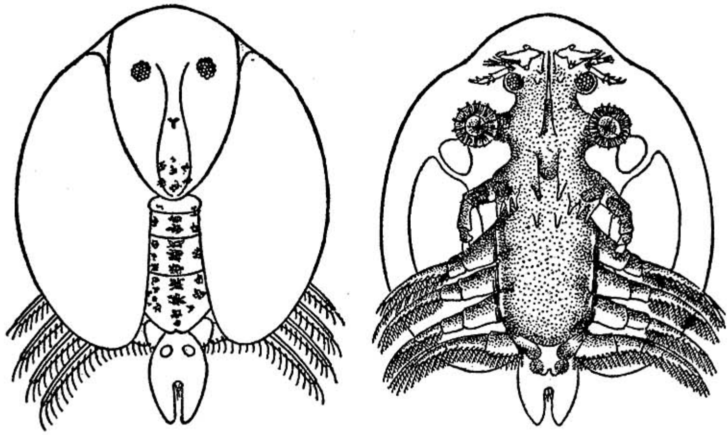


Fig. 19. A parasitic copepod (*Argulus trilineata*) sometimes found on goldfish. Dorsal and ventral views of a female. Note in the ventral view suckers and hooks on the antennae by which she attaches herself to the fish (x 9). After Wilson

anchorage. In the argulids, the anterior maxillipeds are modified into powerful muscular sucking disks; and "by a walking motion of these same disks they scuttle about over the fish's skin so long as it remains moist." The suckers lose their adhesive power on a dry surface. Further to keep from slipping backward off the fish as it darts through the water the argulid's antennae are provided with stout hooks, spines, and bristles, which at the slightest backward movement grip fast to the skin of the fish. The greater the speed and the water pressure, the tighter the argulids stick.

CRUSTACEANS

Cirripedia

The subclass Cirripedia gets its name from the cirruslike or feathery feet of its better known representatives—the barnacles, order Thoracica. The other order—included in the subclass—Rhizocephala is comprised of parasitic degenerates which no one would recognize as Crustacea. Huxley has aptly described a barnacle as an essentially shrimplike form that has become attached by the head to some submerged surface; has incased itself in an armor of stout plates, often fused together; and kicks food into its mouth by means of its filamentous, feathery-appearing feet, which have become characteristically modified for the purpose.

Barnacles fall quite naturally into two categories or suborders—the sessile and the stalked (Fig. 20).

Sessile barnacles are commonly called "acorn shells" or "acorn barnacles" because of their supposed resemblance to the acorn. The soft body of the animal is surrounded by an immovable shelly wall or palisade of plates which grows attached to some means of support, such as stones, piling, ships' bottoms, or the bodies of other animals. The free end of the shell is closed by a four-jointed lid known as an operculum. The technical name of the suborder, Operculata, is derived from this structure. The calcareous covering or wall of the barnacle serves it, in its more or less helpless condition of fixation, as a protection from all aggressors not strong enough to crush it.

The barnacles of the second suborder, the Pedunculata, are likewise attached to a support from which they never escape. The body, however, with its inclosing valves, is elevated on a stalk, or peduncle, which may be fleshy, leathery, or scaly. The valves of the Pedunculata are usually thinner than those of the Operculata and are movably articulated with one another.

The members of the Pedunculata may vary quite widely in appearance and habitat. In some the body is heavily armored with calcareous plates, while in others the plates are incompletely calcified or present only as vestiges. Some are fixed immovably in one spot, while others are attached to large pelagic medusae (jellyfish)

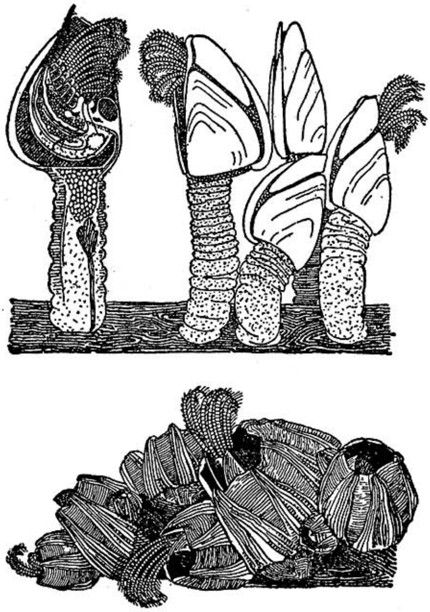


FIG. 20. Stalked and sessile barnacles (*Lepas* and *Balanus*). The stalked barnacle on the left is shown in longitudinal section. The cement gland by which the barnacle attaches itself is seen in the lower half of its fleshy stalk

and are limited in distribution only by the range of their hosts.

But how is one to know that a barnacle is a crustacean? For many, many years barnacles were considered as shellfish and mollusks, along with clams, oysters, snails, mussels, and the like. However, the clue to their crustacean nature lies in their growth stages (Fig. 21), as does that of the parasitic copepods we have just been considering. It is scarcely believable that the young barnacle emerges from the egg as a nauplius, like any other entomostracan; but with few exceptions it does. The nauplius

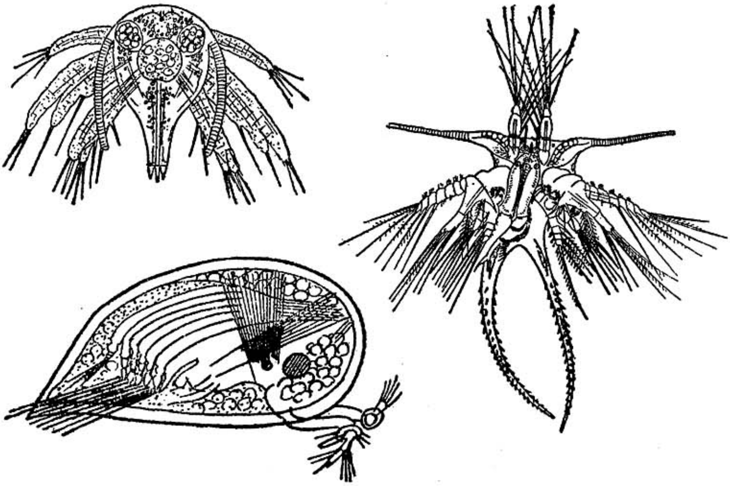


FIG. 21. Three larval stages of a stalked barnacle (*Lepas*). Upper left, newly hatched nauplius. Right, metanauplius. Lower left, cypris stage. All much enlarged. After Groom and Claus

of the barnacle, in structure, appearance, and behavior, is scarcely to be distinguished from that of any other entomostracan. It progresses through a number of stages with little change in form until it reaches a definite metanauplius stage. This lasts but a short time and at the next molt the young barnacle transforms into a cypris-stage, so called because of the bivalved shell with which the cirriped is provided in this stage and which gives it a resemblance to the real *Cypris*, an ostracod. However, as the larva possesses already the full complement of appendages of the adult barnacle, it is in all essentials a free-swimming cirriped. During this brief period it is free to leave home and seek its own fortune, which it does by finding a suitable place of settlement. To this it attaches itself by means of the cement glands with which it is provided, and goes about the business of being a recognizable barnacle for the rest of its natural life. The free-swimming larval stages permit the otherwise sessile, sedentary barnacles to scatter to the four corners of the marine world. Some are found only in very restricted localities; while others, like those that are seen on the hulls of ships, range the Seven Seas.

Barnacles of the genus *Chelonobia* are found on the shells of sea turtles, a location for which they are structurally well adapted. Others are found attached only to whales. Mr. Ira Cornwall has observed that these species have accommodated themselves most wonderfully to the 10,000-mile voyages indulged in by their mighty hosts, during which the whales journey from their breeding ground in the equatorial seas to their summer feeding grounds in the shadow of the poles. To cope with the extremes of environment confronting the animals in the course of the whales' migration—especially the sojourn in tropic seas—certain of the whale barnacles of the genus *Coronula* possess the largest and most highly developed gills, or branchiae, of any cirripeds known. As Mr. Cornwall explains, "It is well known that the warm water of the tropical seas contains less oxygen than the cooler water of the northern and southern oceans; also the increase of temperature causes an increase of the rate of metabolism, and a consequent greater demand for oxygen. The combination of these two factors would explain the great development of the branchiae of the barnacles." He also remarks that this would account for the large gills of another crustacean found on whales, "the amphipod *Paracyamus boopis*, the common 'whale louse,' which is found in thousands on and among the barnacles of the whales."

And how differently do the several species of whale barnacles attach themselves to their host! *Coronula reginae*, with very few exceptions, is "found only on the lips and the front edge of the flippers"; *Coronula diadema* in heavy masses on the throat and corrugated belly. The latter "is not embedded in the [whale's] skin at any stage of its development, while *C. reginae* commences its growth below the surface, only the hood projecting above the level of the skin. As the shell grows, the skin is forced back till about a third of the shell is exposed. . . . *C. diadema* is barrel-shaped, and its station brings its opening nearly at right angles to the line of motion of the whale. *C. reginae* is much depressed, and it is situated in such a way as to bring its opening facing forward." Another peculiar barnacle, also found on whales, is so attached to the flippers and flukes that its opening faces backward when the whale is in motion. This barnacle has been reported as occurring on porpoises also. The rarest of the whale barnacles in American collections is a small, tubular, storied-looking affair, *Tubicinella major*. It is found on the upper jaw, on the forehead, and over the eye of the southern right whale. *Stomatolepas*, as the name indicates, is found embedded in the mucous membrane of the gullet of sea turtles. *Platylepas* lives embedded in the skin of turtles and in that of manatees, sea snakes, and fishes as well.

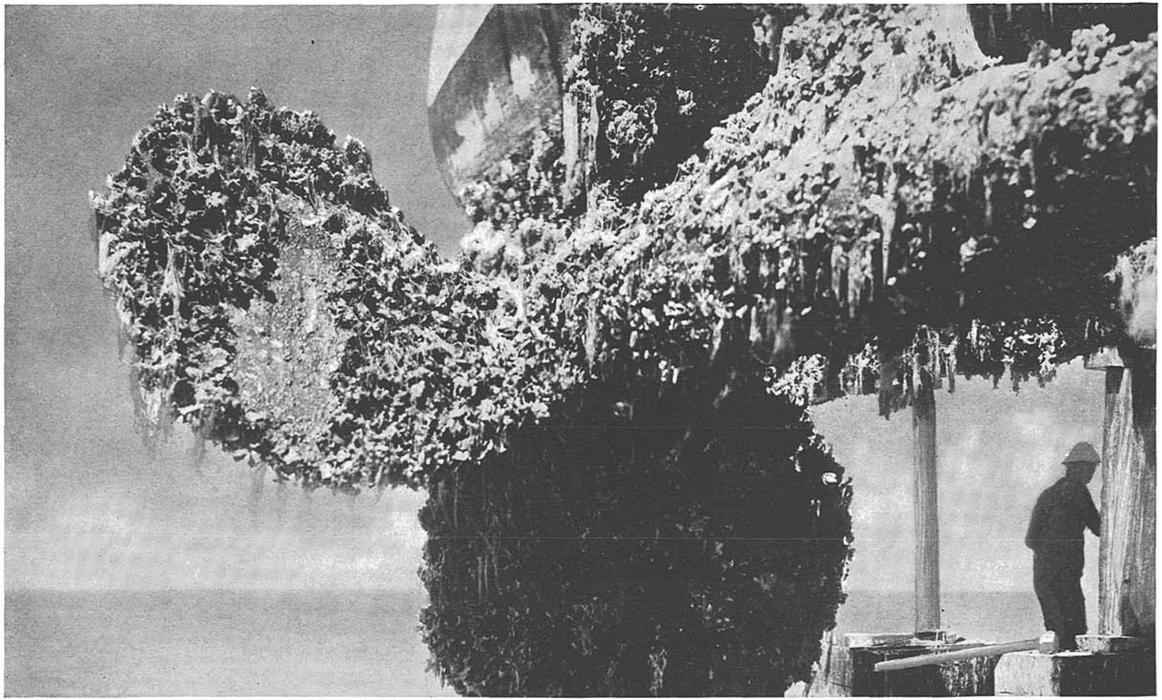
In the course of a study of the bottoms of some 250 ships calling at Atlantic coast ports of the United States, not less than sixteen species of barnacles were enumerated. Barnacles are among the organisms that contribute most toward the fouling of ships; and they have the added disadvantage, from the mariner's standpoint, that their shells remain even after they die, and can be removed only when the vessel is docked and scraped. Softer animals and seaweeds tend to die and rot off when moved from warm to cold or from fresh to salt water or *vice versa*. Fouling may diminish the speed of a vessel as much as fifty per cent and increase the time required for a voyage from ten to fifty per cent; it causes an increase of fuel consumption, with corresponding wear and tear on the machinery, and necessitates frequent docking. Docking and scraping is the only sure method of keeping down underwater growths on vessels. It costs approximately $100,000 to dry-dock, clean, and paint such a vessel as the *Leviathan* or the *Majestic*, each of which has more than an acre of surface under water. The barnacle proved to be the principal fouling organism in 116 out of 217 vessels, and the second most important factor in 36 others. Crustaceans do take their toll of ships and shippers. According to the United States Bureau of Fisheries, heavily fouled ships frequently carry more than 100 tons of fouling material and occasionally more than 300 tons. It is conservatively estimated that the annual cost of fouling to the shipping industry of our country is in excess of $100,000,000.

But barnacles have their uses as well as their drawbacks from man's point of view. In Chile, where a common species grows to a prodigious size (for a barnacle)—nine inches in length and several inches across—the meat of this shrimp relative is an important article of food. It is considered quite a delicacy and is much sought after as an ingredient of soups and chowders. The flavor—all its own—of this barnacle soup is equal to that of the best clam chowder, while the flesh is more palatable than clam meat. In Japan a small species of barnacle is cultivated on stakes, from which it is scraped off and used as fertilizer.

One of the strangest phenomena about some species of barnacles is that the males are dwarfs. The great majority of Cirripedia are hermaphroditic; but two genera, *Scalpellum* and *Ibla*, have dwarf males comparable to those known in some deep-sea fishes and in certain other crustaceans. These males are often without appreciable structure, and probably all are short-lived. Some of them are attached to hermaphroditic individuals and so seem to be "complemental males," as apparently they are not altogether necessary in the perpetuation of the species. When attached to purely female individuals, however, the dwarf males must be of some use. Such males are structurally more developed—have something of an alimentary tract—and so able to carry on a life of greater duration, but scarcely of greater independence than the "complemental males," as they are confined to the mantle cavity of the female and dependent on her bounty for existence. The less developed dwarf males lack both the means of acquiring sustenance and the organs to assimilate it. They suggest at once the May flies, the males of which have neither mouth, stomach, nor other means of taking nourishment. They exist solely for the purpose of perpetuating the species, and when that vital function is discharged, they pay the supreme sacrifice. So it is, no doubt, with the dwarf males of barnacles, which do not, and perhaps can not, feed even if they would.

Before leaving the barnacles some mention needs to be made of their "poor" relations—the rhizocephalids (order Rhizocephala), which have become such abject parasites as not to be recognizable as barnacles, or even as crustaceans, if it were not for their life history. The rhizocephalids prey on other crustaceans only. Found parasitic almost exclusively on decapod Crustacea, the full-grown rhizocephalid appears superficially little more than a tumorous growth attached to the underside of the abdomen of the host.

An adult rhizocephalid is a mere envelope of thin chitin: it shows no trace of segmentation, appendages, or even an alimentary tract. It carries a visceral mass and reproductive organs (usually male and female in the one animal), and is nourished by a threadlike absorptive root system which penetrates the body of its host in all directions. Its effect on male decapod hosts is profound, resulting in an apparent unsexing. The male crabs, par-



Heavy accumulations of barnacles and other marine organisms fouling a ship's propeller. After Visscher.
Courtesy of the Bureau of Fisheries

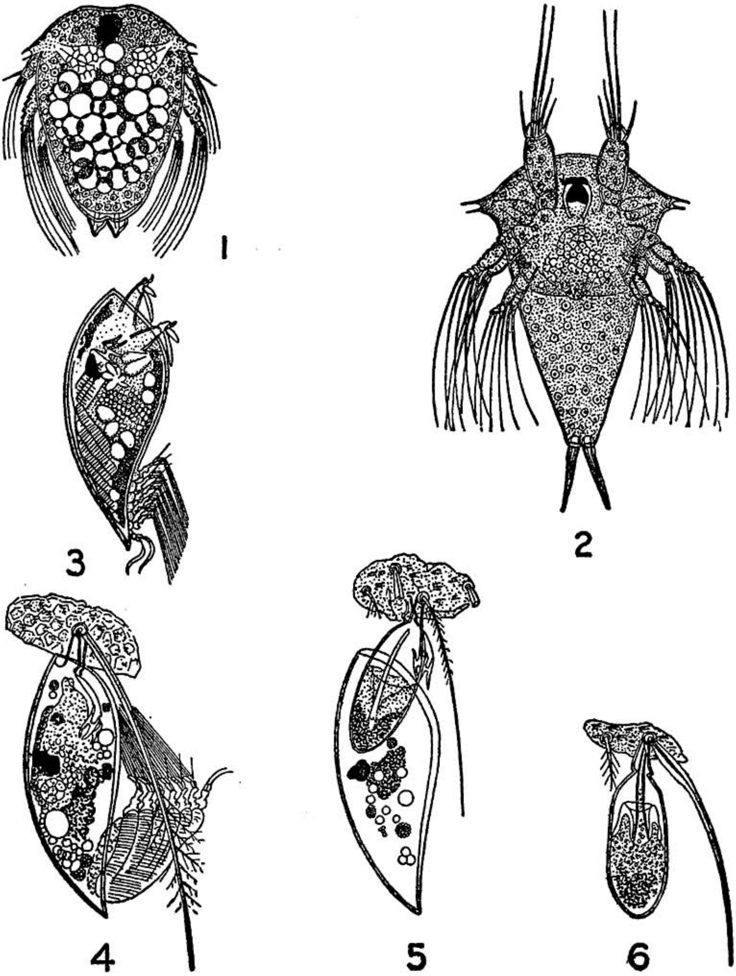


FIG. 22. Stages in the development of the parasitic rhizocephalid *Sacculina carcini*. 1, nauplius newly hatched; 2, after the first molt; 3, free-swimming cypris stage; 4, cypris stage attached to a seta of the host crab; 5, larva still attached and in act of casting cypris shell; "dart" almost formed; 6, dart beginning to penetrate shell of host at base of a seta. All much enenlarged. After Delage

ticularly, when infested with rhizocephalids, tend to take on the secondary female characters of their kind, most noticeably the broader abdomen of the female (Fig. 23).

But stranger than its structure or than its effect on its host's structure is the life history of the rhizocephalid (Fig. 22). Hatching out usually as a nauplius and transforming into a cypris stage, like any normal barnacle, it

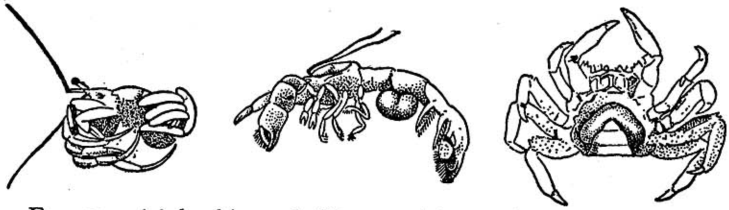


FIG. 23. Adult rhizocephalids parasitic on the abdomen of a hermit crab, a burrowing shrimp, and a crab. Twenty-two individuals of the sausage-shaped species *Peltogaster socialis* have been found on a single hermit crab. After Smith

settles down usually on some decapod host. It is selective, however, in its choice of hosts. Some forms will infest only one species of crustacean. The larva settles down on the host wherever it can find lodgment, though, seldom, if ever, on the abdomen, where the adult rhizocephalid is found. Probably burrowing downward at the base of a hair or seta through the integument of a newly molted decapod, the larva undergoes some remarkable changes in order to work its way through the body of its host and finally, in an unexplained manner, to find lodgment above the abdominal wall. Here it begins to send out rootlike processes, which cause degeneration of the body wall of the host. An opening is formed through which, at the time of one of the molts of the host, the mass of the rhizocephalid takes up its accustomed external position. The parasite then proceeds to suck the vital fluids of the crustacean which carries it and to produce new individuals of its kind, which, in their turn, will infest other crustaceans.

THE FAMILY ALBUM

MALACOSTRACA

We have now returned to our starting point—the subclass Malacostraca, which contains the lobsters, crabs, and shrimps. It contains also many other kinds of crustaceans—as many, in fact, as all the other subclasses of Crustacea put together, so that we may expect to find quite a number of strange forms in this immediate family circle of the familiar decapods. But we have at least one reliable touchstone by which to test any eu- or true malacostracan. That is the possession of nineteen body segments. In the entire subclass Malacostraca, only one restricted group—the Leptostraca—is an exception to the "nineteen-segment" rule. All the other groups conform.

SERIES LEPTOSTRACA

Between the Entomostraca (the group at whose peak stand the barnacles) and the Eumalacostraca there occurs a small, inconspicuous group of crustaceans which possesses some characters of each of the other two. This intermediate group has been classified as the "series" Leptostraca, in contradistinction to the "series" Eumalacostraca (true Malacostraca), which includes all the rest of the subclass to which both belong. A good malacostracan from head to toe and representative of the Leptostraca is *Nebalia bipes* (Fig. 24), which fails of being a eumalacostracan only by the tip of its tail, so to speak. For in its tail lies its distinguishing character, and the evidence of its relationship to the lower orders of Crustacea. While in all true Malacostraca the abdomen is made up of six somites, in the Leptostraca it includes seven, and the telson or tailpiece is forked in a manner reminiscent of the Branchiopoda. Thus the total number of somites in the Leptostraca is twenty instead of nineteen; and so this group tends, however slightly, toward the variability in number of somites that is also a character of the Entomostraca. The carapace of the Leptostraca likewise differs slightly from that of all the true Malacostraca that possess such a thing, for it is hinged on the mid-dorsal line and is provided with an adductor muscle to draw the two halves together. The rostrum is hinged and movable and when

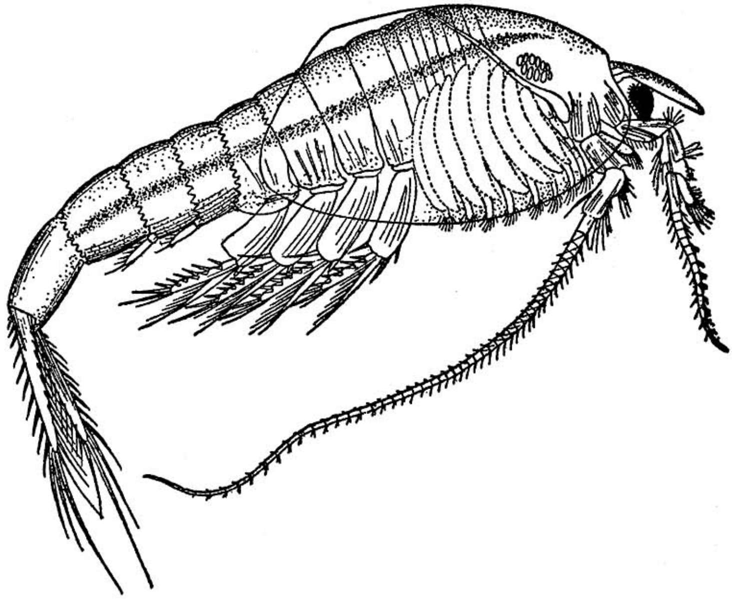


FIG. 24. Female *Nebalia bipes*, showing the forked telson and movable rostrum (x 11). Adapted from Sars

bent down closes the anterior gape of the carapace for all the world like the snap lid on a sirup pot. No doubt this novel shield functions at times to better protect the ova, which are carried by the female in a sort of loose basket formed by the thoracic legs. The young are carried thus until they in great measure resemble the adults.

The Leptostraca are wholly without fresh-water representatives so far as known. Though mostly shallow-water forms, at least one species, a blind one, *Nebalia typhlops*, ranges the intermediate depths of the ocean, from 500 to

750 fathoms down, where it feeds on smaller organisms. Except for *N. typhlops*, the Leptostraca are largely, if not wholly, detritus feeders—stirring up the sea bottom in search of food—and at times scavengers; for a favorite way of securing them in the Dry Tortugas (Florida) is by putting out partly cleaned lobster shells as bait, which as soon as the adhering flesh begins to decay literally swarm with *Nebalia*. Temperature seems to affect but little their life processes. Most Leptostraca measure between three-sixteenths and three-quarters of an inch in length, but the giant among them, *Nebaliopsis typica*, measures more than an inch and a half.

SERIES EUMALACOSTRACA

The "series" of true malacostracans, including as it does the more highly developed and to us the better known and larger crustaceans, comprises ten orders, which seem to fall quite naturally into four major divisions.

Division Syncarida

The most simply organized and most generalized in structure of the true Malacostraca are the syncarid Anaspidacea. This order has the further distinction of comprising fewer individuals and fewer species than any other order of Crustacea except the newly created order Thermosbaenacea, which has but a single representative. Anaspidacea is made up of a bare half-dozen species, divided among four genera. Three species are confined to the antipodes, and three are restricted to the subterranean waters of central Europe. The largest, *Anaspides tasmaniae* (Fig. 25), grows to be one and a half inches in length and is found only in the mountain lakes and streams of the southern and western parts of Tasmania, at elevations ranging from 2,000 to 4,000 feet. A prime condition of its occurrence is ice-cold water of absolute clarity.

Although a very long way from Australia, Europe, long before the discovery of *Anaspides* in the newer country, had known an obscure little syncarid crustacean, *Bathynella natans*, described in 1882 by Vejdovsky from a well

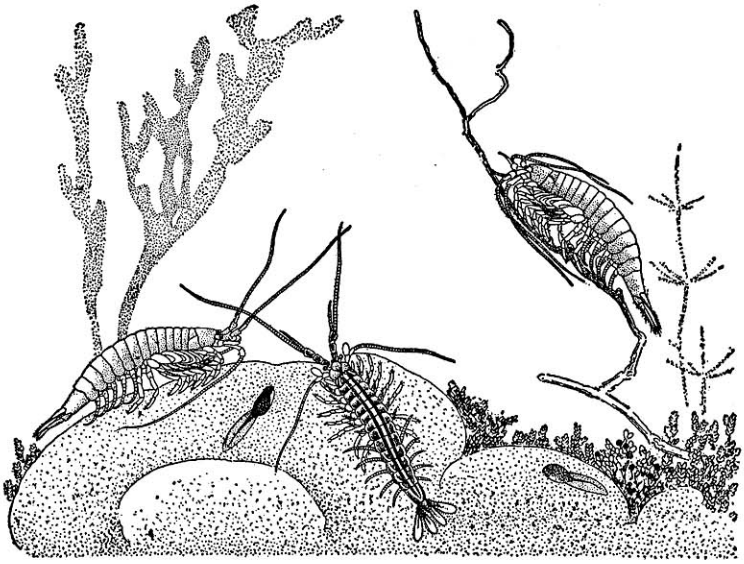


FIG. 25. *Anaspides tasmaniae*, one of the simplest of the malacostracans, on a lake bottom. Black spots in lower right are eggs. Adapted from various authors

at Prague, Czechoslovakia. This well has long since ceased to exist. Not until three decades later, 1913, was the species rediscovered. Then it was found in a spring at Basel, Switzerland, which also, like the well at Prague, subsequently became filled in. After that, at intervals of a few years, the species was noted in other wells at Basel and in some Serbian caves; and as late as October, 1925, it was found in the water mains of the town of Oefingen, Germany. Still more recently another syncarid, as yet undescribed, has been reported from a cavern puddle at Kwala Lumpur, Malacca, Straits Settlements. The bathynellids are completely subterranean in their habits, and as completely lacking in eyes. Occasionally they may swim short stretches; but most of the time they spend crawling over the bottom, carefully feeling for the microscopic, unicellular rhizopod protozoans upon which they feed.

Why do these minute European crustaceans find their nearest relatives in far-off Tasmania and Australia? That is one of the many mysteries of zoology. That they are archaic forms is suggested by the habit which the female *Anaspides* has of depositing her eggs instead of carrying them, as do nearly all Malacostraca.

Division Peracarida

Order Mysidacea

Of the six orders comprising the division Peracarida, the first, Mysidacea, divides honors with the copepods and ostracods as a food for marine animals in all the oceans and in many of the lakes and smaller bodies of water in the

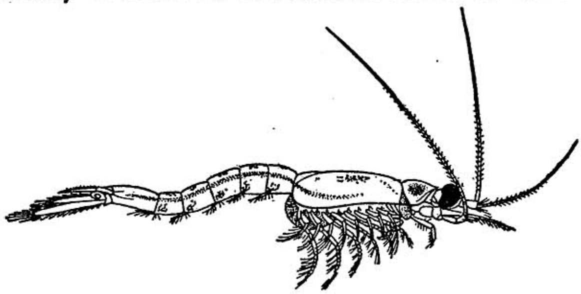


Fig. 26. A fresh-water opossum shrimp, *Mysis relicta*. The brood pouch shows between the thoracic feet. After Sars

Northern Hemisphere. In our own Great Lakes *Mysis relicta* forms from eighty to a hundred per cent of the food of the chub, a commercially important fish. The mysids are small but prolific, occurring in incalculable numbers.

"Opossum shrimp" is the vernacular name of the order

Mysidacea, inspired by the brood pouch (Fig. 26), formed by specially developed plates on the inner sides of the thoracic feet of the female. In this the eggs are hatched and the young sheltered until they can strike out for themselves with a full complement of well-developed appendages. The possession of such an incubative arrangement by the female is one of the distinguishing characters shared in common by all good peracaridans.

The Mysidacea, with the exception of a few rare forms, are without gills as we know them in the higher Crustacea, and even in these exceptional forms the gills are but rudimentary. Furthermore, the mysidacean carapace fails to unite dorsally with at least the last four thoracic somites. These and other facts have dissolved the former union in classification of this order with the order Euphausiacea, which was based on the similarity of appearance

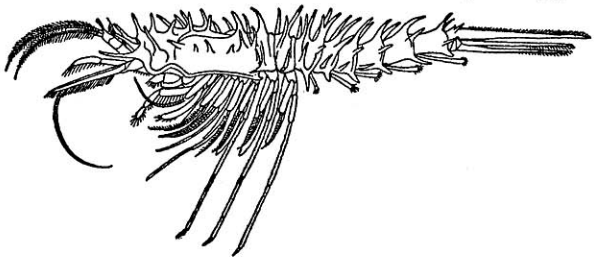
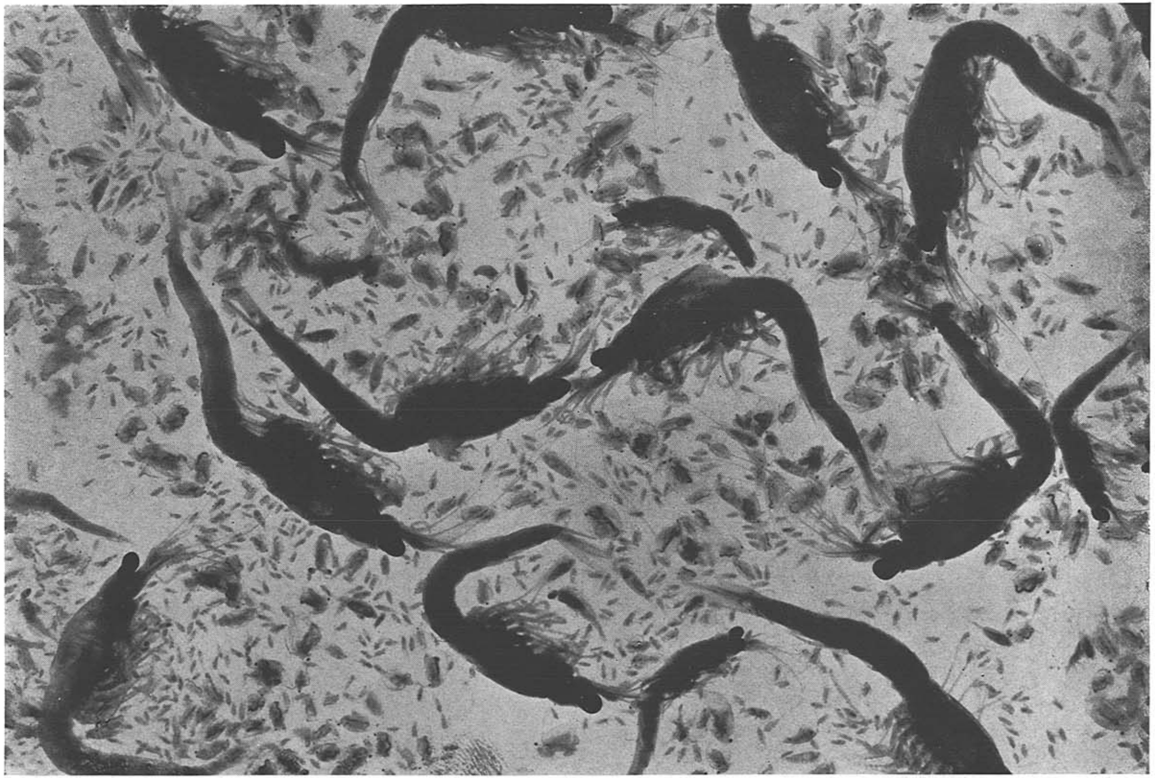


FIG. 27. A spiny deep-sea mysid (*Ceratomysis spinosa*) from 782 fathoms. After Faxon

and the characteristic development of the two-branched thoracic appendages in the two orders. Because of this common character, these two otherwise diverse orders were at one time classed together as the schizopod (split-foot) crustaceans.

The filamentous schizopods, or split feet, of the mysids are their means of locomotion and respiration; and they also produce a current in the water which wafts and drives the finer particles of food and detritus within reach of the mouth and its accessory appendages.



A community of opossum shrimp (*Mysis relicta*), cladocerans (including *Daphnia pulex*), and copepods (including *Diaptomus*) from the depths of Lake Erie. Courtesy of the Buffalo Museum of Science

Mysids seem never to have become parasites, though they themselves are much plagued by isopods, which seem to leave untouched scarcely any group of marine animals whatsoever except such as are too small to furnish them a foothold or nourishment. Protozoan colonies have also been found infesting certain species of mysids. Subterranean mysids are known, one from a grotto in Madagascar, and another from Italian caves. One is even said to be commensal in the shell of a hermit crab.

Order Thermosbaenacea

This is a newly recognized order of Crustacea, proposed since the first draft of this paper was written, an apt reminder that the day of carcinological discoveries is not yet past and that there is still a very fruitful field awaiting investigation by the student and the explorer.

Thermosbaena mirabilis Monod (Fig. 28) was first collected in 1923, from a shallow hot spring in the vicinity

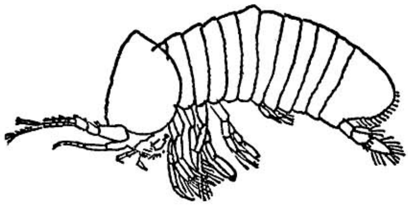


Fig. 28. *Thermosbaena mirabilis* from a hot spring near Tunis (x 15). After Monod

of the ruins of an old Roman bath near Tunis (North Africa). So strange was it and so different from all other known crustaceans that not until 1927 was a place found for it in the classificatory scheme. That place was the new order, Thermosbaenacea, lying close to the Mysidacea.

So small is the animal—two to three millimeters long—that it was at first thought to be a larva or some other juvenile form of an unknown crustacean. The body of

Thermosbaena is short and stubby, and the body regions are scarcely to be distinguished one from another without close examination. No trace of eyes or eye stalks has been found, and all the appendages are on quite a simplified or primitive plan. The mature female has a functional marsupium for sheltering the developing eggs.

The temperature of the hot springs in which *Thermosbaena* was found reaches 112° Fahrenheit. In these calorific surroundings it never swims, but crawls about on the shaded rocky walls of the spring, no doubt feeding on the only other organic life found in these waters—a species of blue-green alga which thickly coats the sides of the spring.

Order Cumacea

Third among the orders of the division Peracarida are "some little wonders and queer blunders," the Cumacea, so odd and characteristic of build—and, one is apt to feel, of personality—that once you have made the acquaintance of one or two of them you will forever after be able to recognize them in any gathering of Crustacea. With a carapace that is apparently too large for them (yet fails to protect the whole of the thorax) and a slender, feeble-looking abdomen that seems much too small, their little misshapen bodies are quite unforgettable. But nature has her plans and purposes, though most of them are yet unknown to us. What strikes us as a seeming lack of balance between the fore and hinder parts of the body is no doubt the most efficient combination that could be contrived to facilitate plowing through the mud and detritus in which the cumacean lives and feeds. We do know that the abdomen is most freely movable. The animal can reach all parts of his body with the caudal fork. In spite of his messy surroundings he is a cleanly little beggar, forever furbishing up one or another part of his external anatomy with his mobile tail, giving special attention to the food-getting appendages, which need frequent cleansing to work at full efficiency.

Small and inconspicuous as these retiring burrowers are, they sometimes occur in such vast numbers as to become an important source of food for fishes. On such occasions the males of a number of species tend to swarm at the sur-

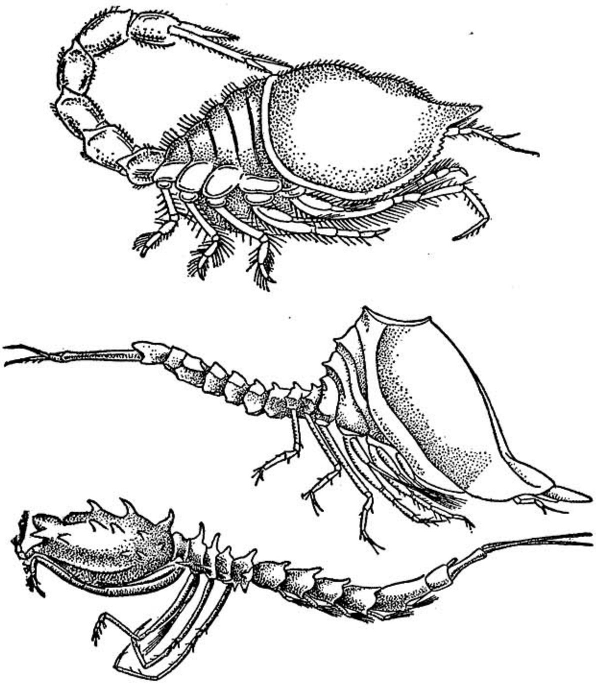


FIG. 29. Representative Cumacea. Upper, the giant *Diastylis goodsiri*, cleaning carapace with the tip of its tail (x 2). Middle, *Ceratocuma horrida*, adult male (x 5). Lower, *Campylaspis vitrea*, young female (x 5). After Sars and Calman

face, especially at night. The male is by far the more active sex and is better provided with pleopods than the female and so better fitted for swimming.

Professor Sars says that by far the greater number of species are pronounced deep-water forms, descending to the greatest depths explored. Cumacea are found in every part of the ocean, and as far north as deep-water exploration has been instituted these peculiar Crustacea have been found to be plentiful. Indeed, in the Arctic Ocean they seem to reach their maximum of development, the huge *Diastylis goodsiri* (Fig. 29) being more than an inch in length.

A further peculiarity of this order noticeable enough to merit comment is its sessile eyes, which are drawn so closely together that they merge into one, giving the Cumacea the cyclopean appearance we had noticed among the Entomostraca.

Order Tanaidacea

Introductory, as it were, to the two final orders comprising the peracarids, we have a small yet well-marked group that are isopods in all but name, the Tanaidacea (Fig. 30). The chief character separating this order from

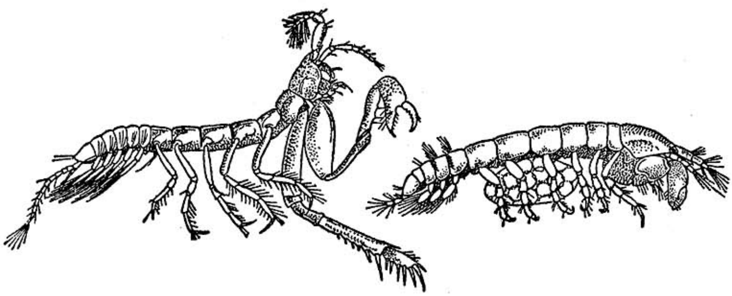


Fig. 30. Tanaids. *Sphyrapus anomalus*, male, and *Tanais tomentosus*, female (x 8), carrying eggs. After Sars

the isopods is the possession of a carapace which coalesces dorsally with the first two thoracic somites, overhanging laterally to form a branchial cavity on either side. Their eyes are a compromise between the stalk- and the sessile-eyed peracarids, inasmuch as those species in which the eyes are not wanting altogether usually have them on little immovable processes on the head, which seem to be analogous with the ocular peduncles of the mysids.

Most of the Tanaidacea are quite minute, about a sixteenth of an inch long. Not much is known of their mode of life, but certain of them live in the mud of the littoral zone or hide away among algae, hydroids, and the like. Not all restrict themselves to shallow water, for some have been taken in the North Pacific from depths exceeding 2,050 fathoms. Certain bottom-dwelling tanaids may spin themselves little tangles of thread, within which to conceal themselves, or else fabricate a tube from their secretions, outwardly incrusting it with bottom materials or plant débris for protection. An American species, *Tanais robustus*, has, I think, the most peculiar plaçe of abode of all the members of the tribe. It was found by its discoverer "inhabiting minute tubes in the crevices between the scales of a turtle's (*Thalassochelys caretta*) carapace."

Orders Isopoda and Amphipoda

For the first time since we took leave of the barnacles we meet crustaceans of which most of us have probably heard before; namely the Isopoda (to which belong the better-known wood-lice, or pill-bugs, found under stones in damp places) and the Amphipoda (which include the sand-hoppers, or sand-fleas, with which all visitors to the sea-shore are familiar). Both orders contain, in addition, many salt- and fresh-water forms which are not so well known.

But how is one to tell an amphipod from an isopod? The two are so much alike and so much akin that only a combination of rather detailed characters serves as a sure means of distinguishing them. For a superficial—though by no means universal—rule, one might say that the isopods are depressed, that is, flattened from above and below, whereas the amphipods are compressed—flattened from side to side. Also, isopods generally lack claws, whereas all amphipods have them.

In alluding to the amphipods, Stebbing referred to them as the "many twinkling feet." To examine their many and diverse appendages is to discover that they carry about with them almost as many tools as the proverbial plumber. In one and the same animal the different appendages are adapted to such various uses as feeling, biting, culling, holding, back brushing, shoe polishing, swimming, jumping and what not.

"Among the Amphipoda," to quote Dr. Stebbing again, "there are a few species armed with strictly defensive spines, but otherwise they are of all the Malacostraca the most absolutely and universally peaceable towards mankind, never inflicting upon him any personal injury whatever." The same might be said, also, of the amphipods' attitude toward animals other than man. They are primarily the most efficient scavengers of sea and shore, the multiplicity of them rendering them of more service in clearing up organic débris on all the world's shores than any other animals, even those much larger than themselves.

Perhaps the only great harm that can be charged to amphipods is that of destroying wooden harbor works. One species, *Chelura terebrans*, belongs to the great triumvirate of animals most destructive to wood immersed in salt water, the other two members of which are the molluscan shipworms and certain of the isopods, notably *Limnoria lignorum*. The amphipods are ever so much more preyed upon than preying, and few among them—like *Cyamus*, the whale louse—can be classed as at all parasitic. They form the bulk of the food of many animals, particularly fish, and several of the abundant pelagic species are said to form part of the crustacean diet of whales.

Quite otherwise is it with the isopods. Many species are free-swimming scavengers like the amphipods; but no end of them are degenerate parasites, lacking face and figure to such an extent that they can scarce be distinguished from the most depraved rhizocephalid except by the locality of their attack upon the host species and by some minute but peculiar points of their internal anatomy. I refer especially to the bopyrids (Fig. 31), which are a great plague to other and higher crustaceans; for they take

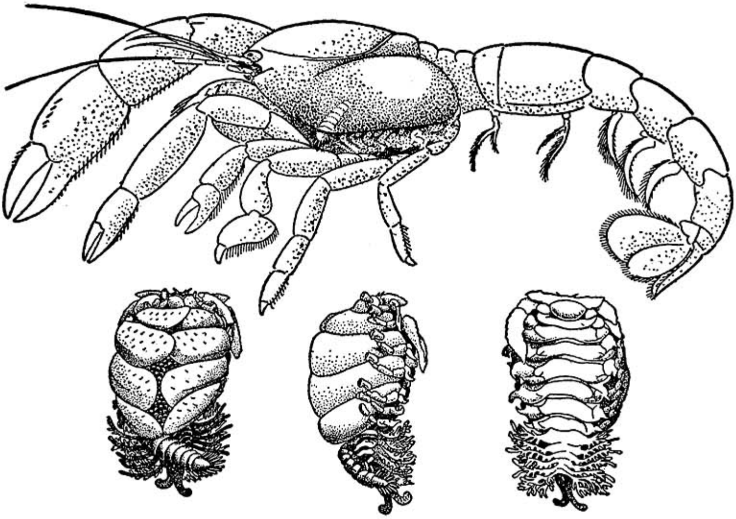


FIG. 31. A degenerate isopod, *Ione thoracica.* Above, a female with a smaller male attached parasitizing the gill chamber of a burrowing shrimp, *Callianassa.* Below, ventral, lateral, and dorsal views of the female (x 4) with the small male in normal position. After Bonnier

their seats upon the gills of the shrimp or crab attacked and cause there a characteristic and readily recognized malformation. As already mentioned in connection with other parasitic crustaceans which prey on members of their class higher in the scale than they, these isopod parasites are themselves parasitized. Also, in the order Isopoda, as in some of the parasitic barnacles and copepods, we find repeated the phenomenon of dwarf males.

Many isopods without such characteristic degeneration of form are ill-natured and are vicious enemies of fish.

The cymothoids, for example, attach themselves to the sides of their unwilling hosts or find a foothold in their mouth cavities (Fig. 32). They must be pain-causing guests, for it is not safe to detach one—no matter how

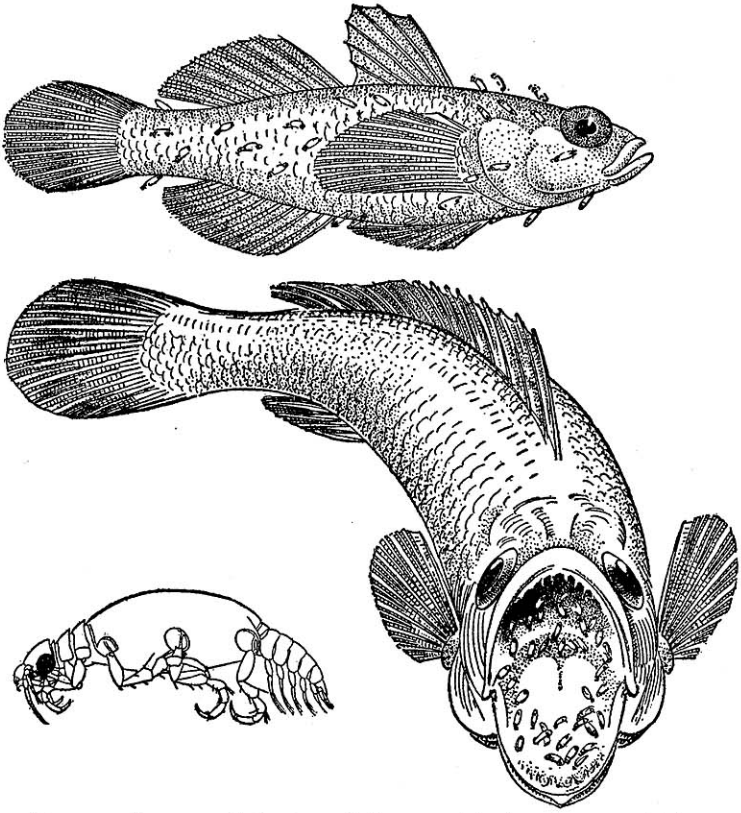
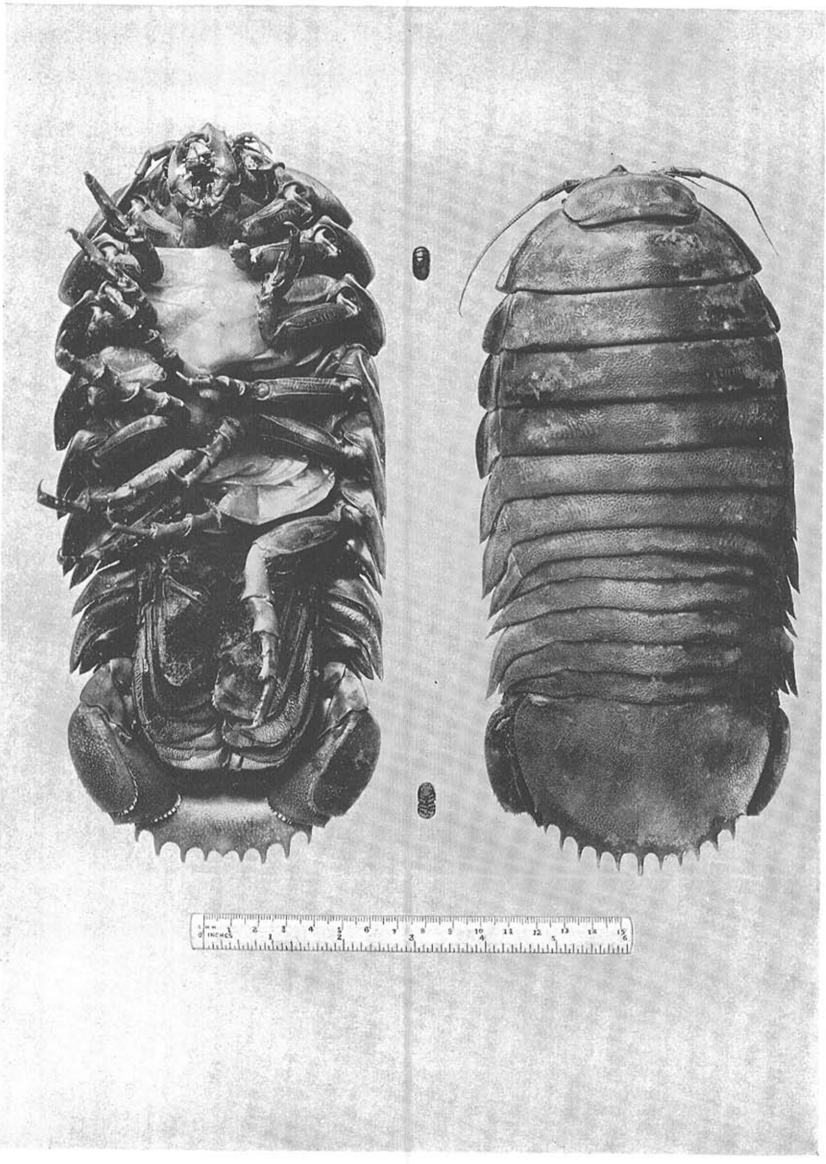


FIG. 32. Larvae of the isopod *Paragnathia formica* parasitizing the skin of a goby and the mouth of a connor. Lower left, an individual larva (x 10). This species is parasitic only in its young stages. Adapted from Monod

small—from its host with the bare hand. There have come to us a number of reports of painful "bites" that cymothoids have inflicted on the unwary by clamping

A female isopod (*Arcturus baffini*) of Greenland, whose antennae serve as a perch for her growing young (slightly enlarged)



The largest known species of isopod (*Bathynomus giganteus*) compared with a common variety (*Armadillidium vulgare*) the wondrous strong and wickedly sharp, sickle-shaped dactyls of their many legs into the unsuspecting palm or finger of the would-be collector.

The young of these isopods just after hatching are worse than a pack of ravenous wolves in the way they assail the nearest fish in their search of a host on which to dwell and feed. Such lilliputian marine battles have, under favorable circumstances, been observed in tide pools, where the fish always seems to get the worst of it.

In speaking of wolfish isopods, Doctor Stebbing says that "if one were a literary fish, one would write with a kind of horror, on account of the appalling diligence which these so-called fish-bears devote to ichthyology. Not contented with persecuting ling and haddock, cod and halibut, they assail with equal fearlessness dog-fish and shark and tunny. An extraordinary feature in the life of some of the cymothoids is the virtual change of sex which is said to occur, enabling the father of one family to become in turn the mother of another, as though the ordinary marital arrangements were not sufficient to perpetuate their malicious brood."

In certain of the astacillid isopods the long antennae of the mother form "a sort of perch to which rows of young ones have repeatedly been found clinging, like wind-waving articles on a laundress's clothesline (Plate 44). One observer has recorded that 'the parent neither testified impatience of their presence nor seemed to suffer any inconvenience under the burden'," but nevertheless as they grew up they did seem ultimately to prove an annoyance, capable even of a fatal termination to the mother if they did not in time go to seek their fortunes in the world.

A striking form among the isopods is *Bathynomus giganteus* (Plate 45), one of the giants among crustaceans, growing to a little over a foot in length. The largest amphipod, *Alicella gigantea* (Fig. 33), is less than half the length of the largest known isopod, but in tenuity of body some amphipods take first place. Many visitors to the

Museum ask to see the skeleton shrimp. They refer to the amphipod *Caprella* (Fig. 34), which for all its slender build and lack of edible meat is one of the best known of crustaceans. *Caprella* turns a ghostly white after being

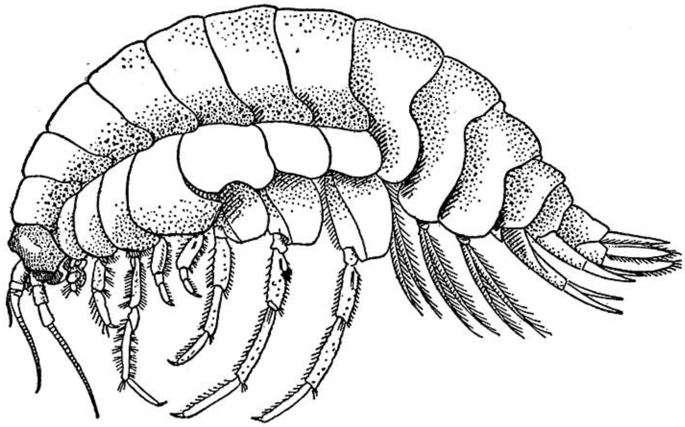


FIG. 33. The largest known amphipod, *Alicella gigantea*. A female five and a half inches long (reduced). After Chevreux

pickled for any length of time, but in life it is among the most adaptable of animals in reproducing the color of its surroundings. Its bodily form is equally imitative of its usual habitat, and as a result of this capacity for mimicry *Caprella* is hard to find, even though it occurs in great numbers. Not without reason is it called "skeleton shrimp": dwelling among the finely branched seaweeds, bryozoa, and hydroids, in shape and posture and color it is for all the world like a short branch of any of these marine growths.

Do not think that the skeleton shrimps are the only mimics among the amphipods. Some of the plumper fellows, too, like the pelagic genus, *Mimonectes*, are no mean imitators. Except for an odd little tail, without which *Mimonectes* wouldn't be an amphipod, the resemblance of the large transparent body of one of these to a floating jellyfish is well-nigh perfect.

When one beholds the hordes of fish that subsist on amphipods alone, the mere number of these crustaceans

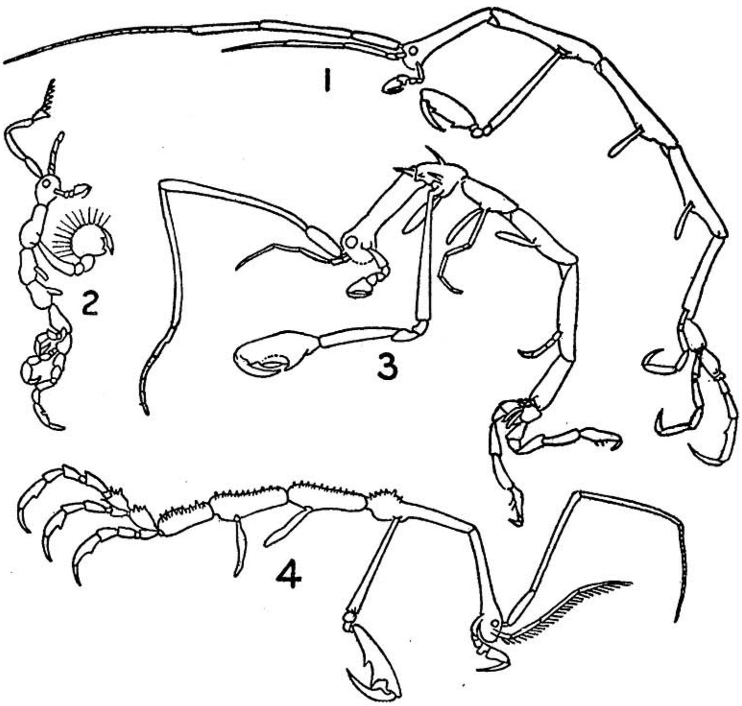


FIG. 34. Caprellid amphipods, aptly called skeleton shrimps, which in color, shape, and posture mimic marine growths. 1, 2, and 4, *Caprella;* 3, *Dodecas*. After Mayer

in the world makes one marvel. Several pelagic amphipods form at times a very considerable part of the diet of the herring and the mackerel. And when the pelagic amphipods are plentiful, then does the Biscayan tunny fishery flourish; when the amphipod food supply falls off, just so surely does the fishery languish. Amphipods that frequent the sea bottom likewise supply much of the food of bottom-feeding fishes of the flounder tribe.

Certain birds also profit largely from the teeming numbers of amphipods. Mr. F. J. Stubbs calculated that in a square mile of sand on the Westmoreland coast of England there were, on an average, twenty amphipods inhabiting each square inch, and that the total weight of crustaceans for the area was seven hundred tons. He was surprised to observe that the only species of bird which seemed to feed on this particularly rich food supply was the black-headed gull.

The amphipods burrow in the sandy mud, making U-shaped passages about two inches in depth. Mr. Stubbs gives a graphic description of how the black-headed gull procures this crustacean food.

> The Gull stands in the water, and, holding its body horizontally, *dances* vigorously with alternate steps for a minute or more, but with no change of position. This action on the sand, possibly by filling up the burrows, alarms the crustaceans, which rise to the water and scatter in flight. As soon as they appear the bird stops its dance for a second or so, and, still remaining precisely in the same spot, snaps in the water at the swimming animals. On imitating the action with the tips of my fingers, and, of course, with the same result, I found that the crustaceans were readily detected by the sense of touch as they struggled to the water; and this suggested the possibility of the webs of the Gull's toes being used as tactile organs. The point is well worth consideration, for if established it would explain the presence of highly developed webs in birds which are addicted to wading but rarely use their feet in swimming.
>
> Sometimes a Gull would remain in one spot for so long a period as half an hour, gravely and patiently dancing the whole of the time. The result would be a craterlike depression six inches in diameter and an inch deep; but, if the birds were not disturbed, they would move gradually *backwards*, and in the course of a few hours make shallow furrows varying in length from a foot to twelve yards. One furrow that I measured was exactly twelve yards long, and had occupied its maker for at least three hours, and possibly twice this time. Now, allowing the width of the disturbed sand to be six inches (really this is the distance between the summits of the ridges thrown up on each side of the furrow), and the number of crustaceans twenty to the square inch, we find the total weight to be about a pound and a half. The

greater part of this would go down the throat of the bird, for I do not think that many of the crustaceans are allowed to escape once they are driven from their burrows.

Division Eucarida

Order Euphausiacea

Men and whales alike, on purely selfish grounds, would put the two orders contained in the division Eucarida first in importance among Crustacea; for these two orders are our old friends the Decapoda, preferred of men, and the Euphausiacea, preferred of whales. But however much they may be strangers to his palate, the euphausids are not unknown to man. No traveler on the Atlantic or Pacific Ocean, especially in the colder reaches, who has leaned over the rail of his ship at night can have missed the sparkles of light in the waves turned back from the vessel's sides and in its wake. These are the flashings of the tiny "lamps" ornamenting the bodies and appendages of euphausids. For all of them except a single genus have organs capable of emitting light. (See Plate 32.)

A euphausid is, perhaps, in an evolutionary sense, a grown-up mysid. It has a carapace which is fused dorsally with all the thoracic somites, and beneath which feather-like gills show plainly. As in the mysid, all of the thoracic appendages carry swimming exopodites, giving the legs the characteristic split-foot appearance. Euphausids are distributed the world over, but only in salt and brackish waters; unlike the mysids, they seem to have no fresh-water representatives. Most species of them range from half an inch to an inch and a quarter in length. The largest known euphausid is *Euphausia superba*, a handsome, brilliant-red fellow exceeding two inches in length. All expeditions to the Antarctic encounter them.

This giant and at least one other species of euphausid constitute the major part of the diet of the Antarctic whales. Sixty-two per cent of the world's whale oil, taken from some thirty thousand whales each year, originates in the Antarctic region and depends wholly on the euphausids the whales get to eat. A moderate-sized blue whale tucks a mere two or three tons of them under his waistline at a meal! And whales are only one of the many kinds of animals that feast on this rich and plentiful food; for the seals and the penguins and petrels of these southern seas are almost, if not wholly, dependent on the euphausids. The North Atlantic *Meganyctiphanes* is a prime whale food, and the finback is at times literally packed with them. The finback is but one kind among a number of the whales that eat euphausids, and *Meganyctiphanes* is but one kind among a number of the euphausids eaten by whales.

Order Decapoda

Second of tne eucarid crustaceans and topping the crustacean scheme of things is the order Decapoda. Systematically it is subdivided into two major groups—the Natantia, or swimmers (best described as the true shrimps or prawns), and the Reptantia, or crawlers (crawfishes, lobsters, crabs, and their allies). As the name Decapoda implies, the members of this order are ten-footed. Quite readily may they be distinguished by this character and by the well-developed carapace which covers the united head and thorax. It is true that in some crablike forms—the lithodid and the porcellanid crabs—the hind legs are small and sometimes tucked in under the edges of the carapace so that their possessors appear to be eight-legged rather than ten-legged; also that in some of the lesser known shrimps one of the five pairs of thoracic legs may be suppressed; but all in all the build of a decapod is so unmistakably shrimplike or crablike that we have no hesitation about its proper classification.

In only one group of decapods do the young hatch out in a nauplius stage, for all the world like a barnacle or copepod nauplius; and only in this same group, also, do the females deposit their eggs instead of carrying them until they hatch. The members of this group are called peneids. As yet the life history of these valuable food shrimps is rather imperfectly known. We do know the nauplius and

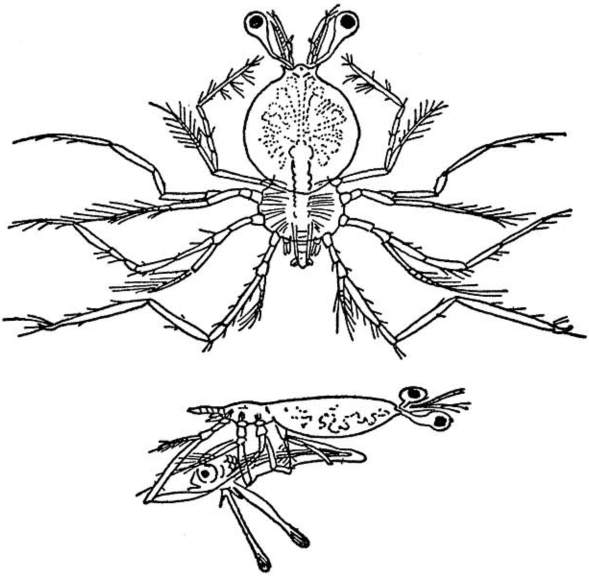


FIG. 35. Upper, dorsal view of phyllosome larva of the English rock or spiny lobster (*Palinurus vulgaris*) (x 7). Lower, a larva capturing a baby angler fish. After Lebour

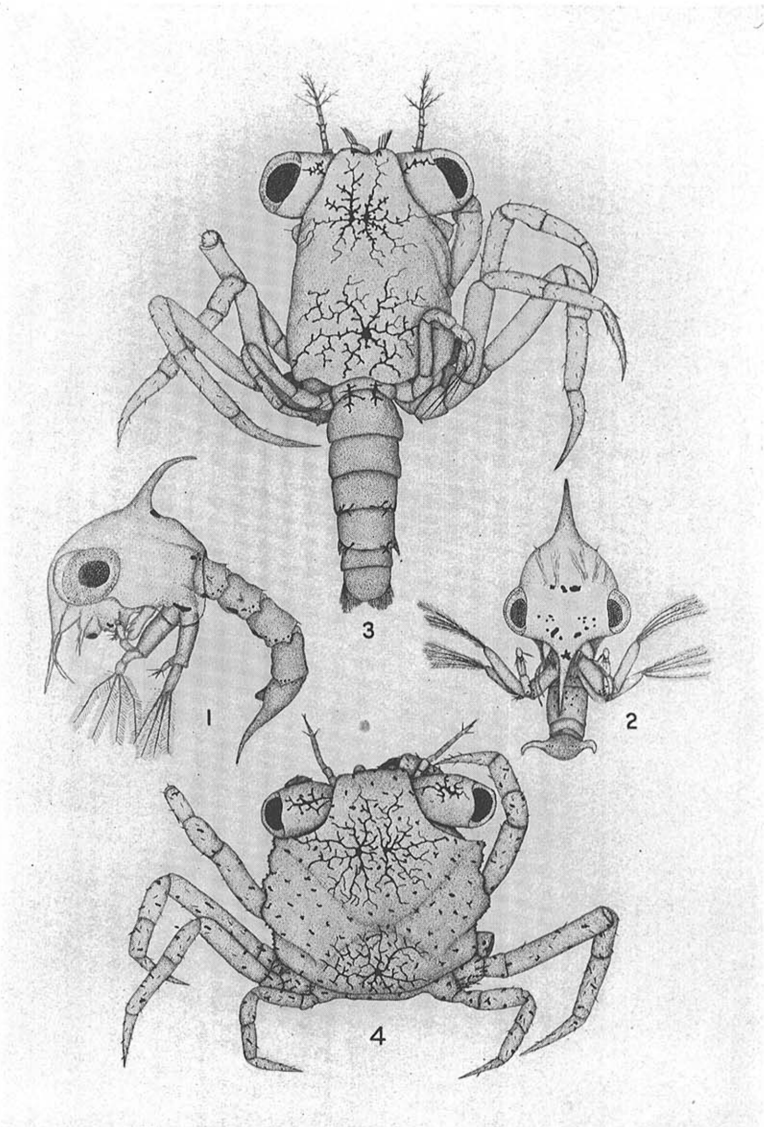
several protozoeal stages, a zoea, and schizopod or Mysis stage; but beyond and between, nothing. And the reason we know nothing of the other stages is because, as mentioned above, the peneids do not carry their eggs until they hatch.

No decapod except the peneids hatches out of the egg at a stage earlier than a zoea, and a few species leave the egg not so very unlike their adult forms. The spiny lobsters and the shovel-nosed shrimps are unique in hatching out in a form quite unknown in other Crustacea. This form is called the phyllosoma-larva or "glass" shrimp, so thin, flat, and transparent is it (Fig. 35). Swimming in its native element it just can not be seen by human eyes. Only in a bucket of water in which the sun is shining can one detect its presence by virtue of the shadow it casts, which is due to the difference of the refractive index of the phyllosome from that of the surrounding water. Out of water, at the bottom of one's net, it appears as a bit of crumpled gelatine, so easily does it "kink" when removed from its supporting medium. The little phyllosome passes through a dozen or two larval stages which give no hint at all of its adult form. Suddenly it transforms into a tiny, smooth, nonspiny lobsterlike being, itself so unlike the adult that it remained for a long time unassociated in the scientist's mind with the spiny lobster. Finally it acquires its familiar adult form.

To illustrate the life history of a typical reptant decapod, we can do no better than make use of portions of Dr. O. W. Hyman's vivid account of the fiddler crab.

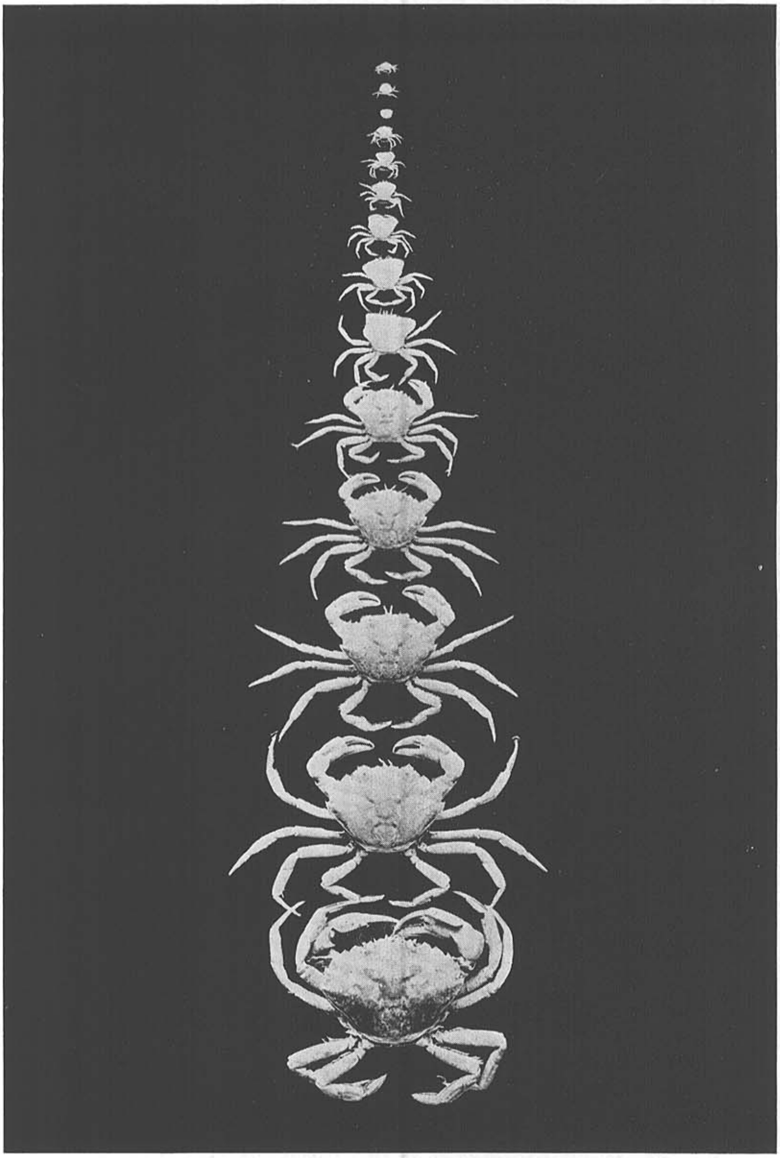
> Hatching always occurs just at dusk—that is, between 7 and 8 o'clock. The mother crab comes down to the water's edge and fans her abdomen back and forth to aerate the eggs as usual. If the embryos are ready to hatch, however, the little larvae burst out of the egg shells and at each forward flirt of the abdomen a small spray of young larvae is shot forward into the water.

The young crab, or zoea, thus catapulted from the shelter of its mother's abdomen, measures only a millimeter in length when fully extended; and as in swimming the body is bent double, the swiftly moving larva is only about half a millimeter in length and the same in width (Plate 46). When the zoea bursts from its eggshell it at once swims to the surface of the water, where it finds conditions that give it a chance to survive. But it is well that the brood is hatched at dusk and has all night to be scattered by the tide before the young members enter upon the adventures of their first day.



Stages in the development of the fiddler crab (*Uca pugilator*). 1, side view of the first zoea. 2, front view of same. 3, megalops. 4, first crab stage (some legs lost). After Hyman

PLATE 47



The finest series of cast crab shells known. Collected from one individual of the English shore crab (*Carcinides maenas*), by Mr. and Mrs. H. J. Waddington (x⅓). Courtesy of the British Museum

The zoea begins to feed upon the smaller of its countless companions at once and for the next four or five days the mouth parts are catching, crushing, and swallowing tiny animals and plants. As a result of this feeding the zoea begins to grow. Its inelastic chitin coat soon becomes too small. A new covering of larger size is formed beneath the old. For a short time now the zoea becomes motionless and sinks toward the bottom. The old coat then splits along the back at the place where the abdomen joins the cephalothorax. The zoea first pushes its body through the slit, and then draws its abdomen and appendages from their old sheaths. This is the first molt. The zoea which emerges is somewhat different from the first hatched zoea and is called the second zoea. The molting period is a perilous time in the life of the zoea. The larva is quite helpless, but fortunately it is almost invisible against the sandy or shelly bottom on which the molt generally occurs.

In the "sand fiddler" studied by Hyman there are zoeal molts at about weekly intervals—four in all, and marked increase in size is noted after each molt. The fourth zoea is just twice as long as the first. The fifth "is no longer the graceful, restless, palpitating form of larva that suggested the name Zoea, 'Life,' to describe it. The body is so heavy that the maxillipeds can only keep it at the surface for short periods. Most of its life is spent drifting along near the bottom."

The last zoeal molt takes place when the animal has been living at sea a little over a month. Of the hundreds of young hatched by one female only a score or so will have survived through this molt, which marks the transition to a new larval stage.

The larva that stretches itself after jerking loose its last attachments to the zoeal skin could hardly be recognized as derived from a zoea—even the changed zoea of the fifth stage. As a matter of fact, it was described by earlier naturalists as an entirely separate genus and called *Megalops*, from its large and prominent eyes. This name has been retained to describe this stage in the larval history, just as pupa describes the second stage in the larval history of the butterflies. The megalops is a larva far different from a pupa, however. Instead of being a motionless, sluggish creature it is a powerfully swimming corsair of the ocean's surface.

. . . It is easily seen as it darts about the surface. The sensory organs are now well developed. The eyes are large and well formed.

In the base of the antennule there is a statolith, and the animal swims about in any direction and can change direction quickly and accurately. It is no longer guided in its movement solely by its reaction to light, but is independent of this tropism and seeks its prey at all depths. It remains at the surface most of the time, however, as food is most abundant there. . . . The animal can hear, in the sense that its delicate hairs perceive the vibrations in the water just as the ears of higher animals record the sound waves of the air. These "hearing" hairs are especially located on the antennae and antennules. . . .

The shape of the body is now more that of a crab than that of a zoea, but in some respects it is intermediate between the two. The spines of the zoeal carapace are lost and the body is somewhat flattened from above and below. However, it is still considerably longer than broad and in this respect resembles somewhat the body of a shrimp. In fact the megalops may be said in general to have the body of a shrimp or crayfish with the legs of a crab. The abdomen is like that of the crayfish and in swimming is carried extended straight out behind. When the animal comes to rest, however, it is folded under the body and the megalops then looks very much like a tiny crab. . . .

The megalops swims about for nearly a month. Unlike the zoea it does not go through a series of molts during this time, although it undergoes considerable internal development. After some three or four weeks of its roving existence these internal changes begin to affect its swimming powers. The swimmerets or pleopods begin to shrivel up slightly. After this begins the megalops is glad to find some convenient place to cling and hide. . . . This loss of the power of the pleopods for swimming marks the end of the sea life and adventures of the larva. When these organs lose their function it will never again be able to swim.

After perhaps a week in its shelter the megalops molts, and out of the megalops shell crawls what is unquestionably a crab, though hardly recognizable yet as a fiddler. After four or more molts in the crab stage the young crab begins to develop secondary sex characters distinguishing the male from the female.

The young crab after this lives just like the adult. It gets its food from the sand on the beach, digs its burrow between the tide lines, comes out and feeds when the tide is falling, and hides in its burrow when the tide is coming in. It continues to grow, and as it grows continues to molt time after time. Of course, as the crab grows larger it digs a deeper and larger burrow. . . .

. . . .

When the weather begins to get cold in the late autumn all the crabs on the beach crawl into their burrows for the winter hibernation. The unlucky larvae and little crabs that are not yet strong enough to dig their burrows perish of exposure during the first cold weather. All during the winter the crabs remain buried. . . .

As soon as the first warm weather comes in spring all the little fiddlers become lively again and dig themselves out. Some of the young crabs of the preceding summer may have become sexually mature by this time and by early April they lay their eggs, and soon the sounds and adjacent sea are receiving new swarms of delicate, active zoeas, setting out upon the great adventures through which every fiddler crab must pass in its youth.

But after all, what are youthful adventures compared to those of a more mature age? The sand fiddlers are agile runners, but a man can easily overtake them. As a protection from their enemies they rely in the main upon their burrows. These are dug along the beach just below the high-tide line and extend downward a foot or more at a very steep angle. When the tide comes in the crabs crawl into their burrows, and the beating of the wavelets soon stops their doors with sand. When the tide begins to ebb and leaves the beach, now all wet, the fiddlers dig themselves out again. The excavated sand is gathered in wet balls and distributed along the beach at a distance of about six or eight inches from the openings of the burrows. It is to be expected that the next time the fiddler enters his burrow he will be in a hurry and want a clear road. After he has made sure of his means of retreat, he joins his companions at the water's edge.

Each wavelet of the receding tide casts up on the beach a tiny "windrow" of sand. There is much more than sand in this "windrow," however. Among the sand grains are caught and left countless numbers of microscopic plants and animals that dwell at the surface of the sea. The fiddlers walk along the "windrows" as they are formed and with the spoon-shaped tips of their smaller claws or hands scoop up the food-laden sand and stuff it into their mouths as fast as their hands will work. At meal times the females have an advantage. Both of their hands have spoon fingers and both are kept busy. The crabs seldom enter the water, although their station so close to the water's edge exposes them to many a ducking in the wavelets. At times, too, when an enemy approaches from the land side the fiddler may elect to hide in the water, partially burying himself in the loose sand, rather than run for the burrow. These short intervals in the water are the most hazardous periods in the lives of adult fiddlers. Blue crabs like to lie in the shallow water and wait for little fish that get stranded, and they have learned that they can also pick up a considerable number of fiddlers. When the tide begins to rise and no new "windrows" are left on the beach the fiddlers will wander elsewhere in search of food. They will climb about over stones or piling at the water's edge and always there are a few that lose their footing in spite of their eight legs and fall overboard. A fiddler overboard is a fiddler lost. They can not swim, and hungry fishes, like the black sea bass and the sheepshead, quickly gobble them down.

As with the fiddler, so with other crabs and decapods with variations to best meet the exigencies of their existence. Concerning the length of time it takes for a typical decapod to reach maturity we cite the opinion of Churchill, who gathered data on the blue crab. This, he says, showed that growth from a megalops larva to the usual adult size required 208 days. During this time fifteen molts took place and the crab grew from a width of a twenty-fifth of an inch to seven inches. The usual term of life for the blue crab, male and female, seems to be about three years. Pearson deduces that the English crab, *Cancer pagurus*, keeps on growing for some twelve years. After the fifth year there is reason to believe that the male molts only once in two years and the female once in three. Judging from the growths of shell and barnacles on old specimens, molting may cease completely as age advances. Incidentally, the finest series of cast shells known is one made up of fifteen shells cast by an English shore crab, *Carcinus maenas*, over a period of three years. The crab molted seventeen times, and all its cast shells are shown in the accompanying photograph (Plate 47) except two which were accidentally destroyed.

We do not know which of the crustaceans is the longest-lived, but it may well be that the full-grown lobster deserves this title of distinction. Lobsters have been known to attain a weight of thirty-five pounds and an age which

Herrick estimates to be about fifty years. A specimen of this weight and age will measure two feet in length of body alone. His large crushing claw may well run to a length of twenty inches and an equal girth; that is, it is as big around as a man's head.

The giant among Crustacea is, of course, that rather fearsome-looking giant spider crab of Japan and the North Pacific, *Macrocheira kaempferi*. (See Plate 36.) It spans twelve feet from tip to tip of outstretched arms, and the body measures eighteen inches across. The spindly legs are almost as big around as an old-fashioned wooden curtain pole.

For the largest fresh-water crayfish we must go to Tasmania, where one species is all of two feet in length and weighs eight or nine pounds. It is excellent eating and much sought after, but the small streams which it frequents seem an incongruous habitat for so large a crustacean.

Within the borders of the United States we have a giant fresh-water shrimp, *Macrobrachium jamaicense*. The largest specimen I know of weighed three pounds; its body length was ten and a half inches; the feelers, which were missing, were said to have been twenty-six and a half inches long; the larger claw of its sturdy pair measured thirteen and a quarter inches. It hailed from the Devil's River, Texas.

Among many fresh-water decapods the young hatch out substantially in the form of the adult. One can readily see the advantage of this to species that may live in steep mountain torrents debouching into the sea, where it is but a hop-skip-and-jump from fresh to salt water; for if the young hatched out in a helpless larval stage they could not escape being washed into the sea, in which they would perish from the salinity, just as we would be overcome by drinking highly concentrated salt solutions.

But among marine species such a suppression of the usually numerous larval transformations is of great rarity.

Of the thousands of species of marine crabs, in but three is there definite evidence of a complete suppression of the larval stages such as we know in fresh-water forms.

The first case of direct development in marine crabs was discovered by Dr. Mary J. Rathbun, Associate in Zoology of the Smithsonian Institution. She found in the brood pouch of a small spider crab—*Naxioides serpulifera*, from the Monte Bello Islands (off the northwest coast of Australia)—young crabs in adult form; and not only in one stage, but in two, showing that at least one molt was undergone while the offspring were still under maternal care. It is of more than passing interest that the other two known instances of direct development in marine crabs should likewise have been found in Australian waters; both were dromid sponge-carrying crabs—*Petalomera lateralis* and *Cryptodromia octodentata*.

The philosopher might find food for reflection in the fact that the most famous of all crustaceans is a thief—the robber crab of the South Seas, *Birgus latro* (Plate 49). He climbs the coconut palm to cut down the meaty nut. Many people have observed the creature at close range and even had him in captivity for considerable periods of time, but never have his habits or his whole life history been investigated with any degree of completeness.

But this much we know. The robber crab is an agile and ready climber, be it on coral blocks, volcanic cliffs, trees, door jambs, posts, or almost anything else that has a perpendicular face. Two of my friends who have had these crabs as pets in their native islands have told me how their sharp-pointed feet would find a foothold in the crevice between the door jamb and the wall and so permit them to climb up with ease; and how on occasion they would travel like a sloth, though not so slowly, along a wire stretched across the room. Just how the crab was said to have descended, I do not at this moment recall. As he makes use of window frames as well as of door jambs, he may drop from the sill to the ground. Kopstein claims that falling with folded legs is his usual mode of descent from palm trees, and says that under these circumstances the crab has to restrict his activities to low trees or else suffer the consequences of wrecking himself on the stones and coral blocks that are commonly found in the coconut groves. But if Kopstein is right in his claims we must admit that the robber is quite a crab to be able to single out the low palms from the high ones in order to make a safe descent.

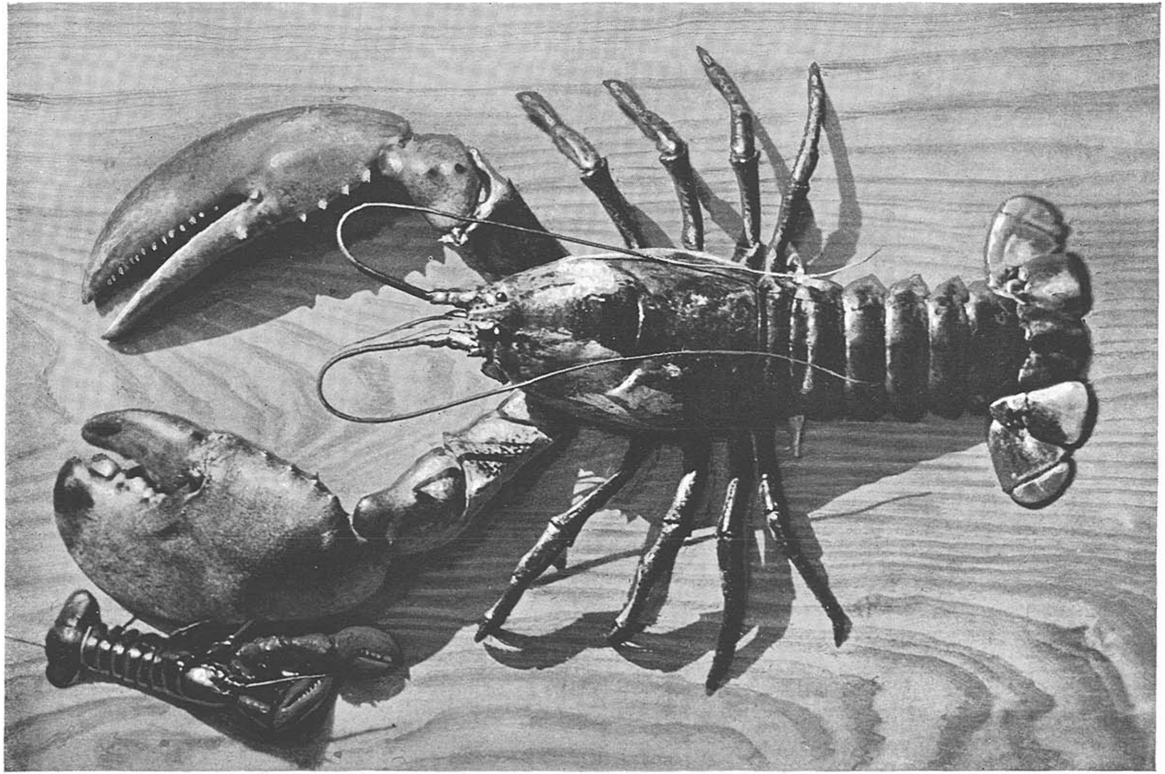
The alleged native method of catching the crabs throws light on the mode of descent of the robber crab. The story is that when a native locates one of these big crabs up a palm tree, he climbs part way up himself and fastens a girdle of grass around the tree. Then he descends. The crab, in his turn, crawls backward down the tree trunk, feeling behind him as he goes. When he feels the girdle of grass he releases his hold on the tree, under the impression that he has reached the ground. As a result he tumbles heavily to the earth, either stunned or killed. At any rate, it is then an easy matter for the native to catch him and tie him up before he recovers from the shock of the fall. The habits of these high-climbing animals do differ in different localities, a fact which accounts for the wide divergence in the accounts about them published by various credible observers.

Professor Sluiter tells us that he has himself seen robber crabs "climbing even to the top of the coco palm and mangrove trees, of 20 m. [over 60 feet] height"; while one he had in his laboratory liked to climb to the tops of the iron pillars supporting the roof—pillars about sixteen feet high and three inches in diameter.

In some districts it would appear that the robber crab makes his home at some distance from the sea, on stony plateaus thirty or forty yards above the shore line; while in the Solomon Islands, Guppy has seen specimens at an elevation of 300 feet. It is here, too, that the robber crab ejects large burrowing land crabs from their homes and takes over their underground habitations. Generally in the South Seas the robber crab seems to stay very close to shore, where he hides among the coral blocks and crevices of the reef, and, more rarely, under the roots of mangroves.

Throughout its range this crab is a nocturnal animal; but Andrews says that on Christmas Island (in the Indian Ocean) it moves about the forest even in the brightest daylight, and he has photographs to prove his statement.

Baiting is an approved method of capturing the robber crab, but hunting him is more popular. On some of the South Pacific islands it is a sport attended with considerable excitement, because of the animal's wary habits, great strength, and bulldog tenacity. Except on Christmas Island the chase is conducted at night, when the robber crab ventures from his daytime hiding places to feed. Improvised torches and lamps furnish the necessary light. When hunting over the reefs in the dark, the well-shod foreigner is at a decided disadvantage compared to the barefooted native, who can stalk the wary game noiselessly. The crab usually scuttles off with awkward yet effective backward rushes, covering several yards with each rush. He never turns tail to the danger. His claws are held presented for instant action, pincers pointing downward, in a posture like that assumed for guarding the head and face in sword exercise, but with the added advantage that it serves to guard not only the crab's head and eyes but his "solar plexus" as well. Then, too, he holds one or both of his needle-sharp second legs poised for a dangerous downward thrust. His poorly armored abdomen is his most vulnerable point. Altogether he is a most doughty combatant when fully on guard, and one that seems to have no enemies to fear except man; although pigs which have run wild are said to attack and destroy the "robber". No doubt if just one pig, or even if just a few pigs, attacked one of these powerful crabs, the crab would be more than a match for his enemy. But wild pigs



A giant specimen of the American lobster (*Homarus americanus*) compared with an ordinary specimen. Length from tip of tail to rostrum, twenty-four inches. Crushing claw sixteen inches long, nine inches wide, and five inches thick. Weight, twenty-eight pounds. Courtesy of Whipple Brothers, Matunuc Beach, Rhode Island

PLATE 49

Robber crab (*Birgus latro*) climbing a coconut tree on Christmas Island.
Photograph by Andrews. Courtesy of the British Museum

have a habit of running in droves, and in a combat with such a drove the odds would be heavily against the crab.

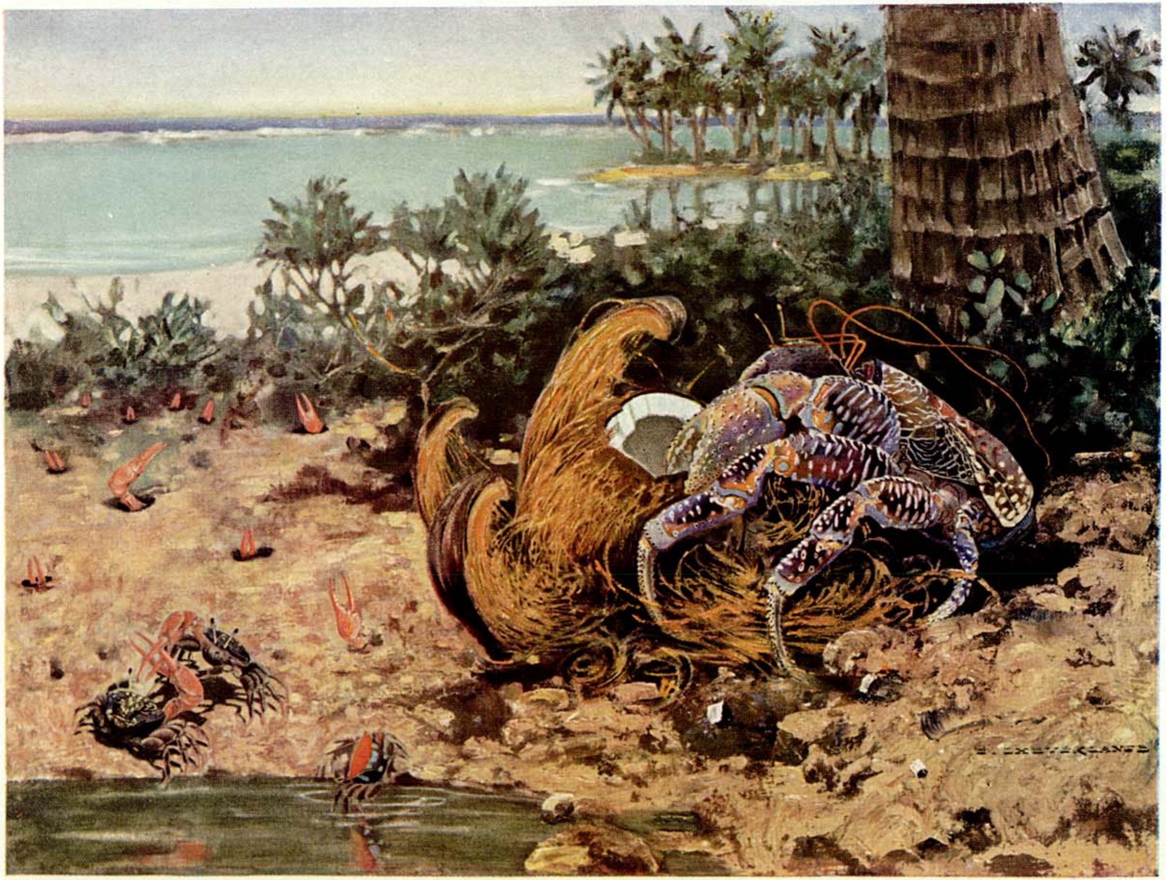
When surprised by torchlight the robber crab must be grasped with celerity by the carapace and held at arm's length until he can otherwise be secured. Woe betide the unskilled hunter who should get caught in his fearsome nippers; for the crab will amputate a finger quicker than it takes to tell about it. Fortunately, should he gain a hold with his claws, there is a little trick that results in instant release, and that is to give the tenacious fellow a rap on the abdomen. Otherwise, he seems able to retain his grip for hours at a time.

Professor Wolf once had occasion to test the endurance of one of these suspended coconut crabs, which had happened to seize the handle of his insect-collecting net. As he couldn't wrench the net out of the animal's grasp, he placed enough stones in it to weigh five and a half pounds. For one full hour the crab showed no sign of fatigue, and it was some hours later before he finally let go his hold. One of Kopstein's captives, a grown specimen about a foot in length, got out one night by cutting a hole through the inch-and-a-quarter wooden wall of his inclosure. This particular animal had pincers as big around as the fist of a ten-year-old child.

Some robber crabs grow to eighteen inches in length and no doubt have claws as large and strong in proportion. No other known animal has the strength and ability to open the tough-husked coconut unaided. The robber crab accomplishes this with neatness and dispatch, and gets out the inner nut as cleanly as any native. He will tackle a tough, ripe nut as readily as the tenderer young green ones, to which many authorities have assumed that he confined his efforts. That the animal can tear off the extremely smooth, coarse-fibered outer casing is less to be wondered at than the facility with which he breaks his way through the adamantine nut within. Commencing operations at the eyed end—structurally the weakest part of the nut—he bites and grinds and nips and perhaps pounds his way through to the juicy pulp within. The entrance he makes need not be overly large, and no sooner is it effected than he holds the shell with his heavy claws and uses his smaller, hinder legs to reach in for the pulp.

Robber crabs from regions where coconuts are to be had will starve rather than take other food; though where coco palms are lacking, as on Christmas Island, they seem willing to eat the fruits of other plants, such as the sago palm and screw pines. A robber crab can readily stow away about two coconuts each three days. In the course of a year, at that rate, he would consume the annual production of two or three coco palms—some two hundred and fifty nuts. So it can readily be seen that he must be reckoned with where coconuts are grown for profit. But his rich diet has made him such a fat and juicy morsel himself that he is considered an epicurean treat by the non-Muhammadan natives, and thus a destructive pest becomes a marketable product. One crab's abdomen will yield as much as a quart of oil. The Chinese, especially, value this crab's flesh as a delicacy; and in regions where the robbers abound, these people frequently keep them tethered about their dwellings—after depriving them of their powerful claws—to fatten them for the table. The orthodox Muhammadans, on the other hand, it is said, are twice interdicted by their religion from partaking of this delectable dish: first, because the animal uses its hand to convey its food to its mouth; and second, because it leads a double life, being a marine animal that passes its life upon the land.

The robber crab does go down to the sea, however, when its eggs are about to hatch, so that its young may be rocked in the cradle of the deep, the ancestral home of all Crustacea. The first free larva is a very ordinary form, like the usual hermit-crab zoea. There is no earmark in the marine young of the robber crab to indicate any great



A scene in the Paumotus: The robber crab (*Birgus latro*) eating a coconut, and fiddler crabs (*Uca tetragonon*) fighting and playing on the beach. By E. Cheverlange

difference between it and the young of the other hermit crabs, which spend their lives in deep water and never venture near the land.

As a result of being so assiduously hunted on economic as well as gastronomic grounds, the robber crab seems to be rapidly disappearing, and in fact has been exterminated on many islands where it formerly abounded.

Division Hoplocarida

Order Stomatopoda

In the stomatopods, or squillas, we have, as it were, an afterthought to the Crustacea. A small and homogeneous group, rather closely adhering to type, they form the single order constituting the fourth and last division of the eumalacostracan Crustacea—the Hoplocarida. Perhaps their most characteristic features are their "jackknife" claws, so like those of our common garden mantis that they are known as mantis shrimps wherever English is spoken. The relatively large and much flattened abdomen is also a very characteristic feature, as is the small, flattened, hinged rostrum, the like of which we have not seen since we left the Leptostraca, the lowest of the malacostracan crustaceans. The eyes, as well as the antennules, are borne on movable "rings" or segments, a character so unusual among the Crustacea that it distinguishes the stomatopods from all other members of the class. Also, the stomatopods are foot breathers in a more specific sense than are other crustaceans, for each of the pleopods or abdominal feet is largely a plumose respiratory organ, and not an accessory to egg-carrying.

The stomatopod young are queer little creatures, as odd in their way as are the phyllosome larvae of the spiny lobster. As glassy as any phyllosome and as long-spined of carapace as anything afloat, these larvae are all planktonic, though the eggs are hatched in the shelter of some recess or hiding place.

Stomatopods are burrowers in mud or sand bottoms, or else they preempt the burrow of some other marine excavator; some live in the interstices of coral reefs. All seem to be most suitably adapted in form and color to the mode of life they lead. In the spinous armature and color of its telson (Fig. 36) one species mimics the tiny sea-

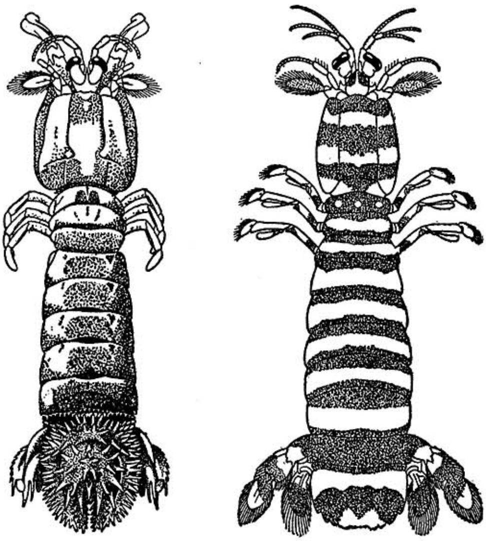
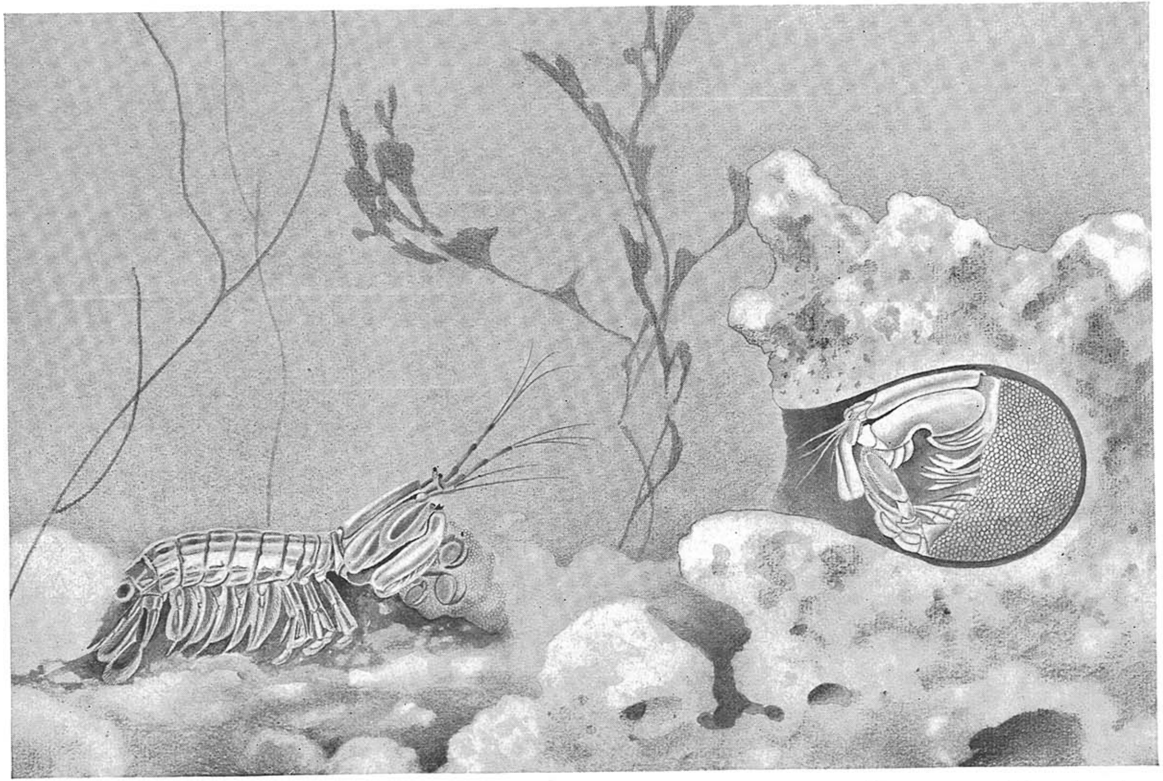


FIG. 36. Stomatopods, or mantis shrimps. Left, *Gonodactylus guerinii* (after Brooks). Right, *Lysiosquilla maculata* (after Kemp), showing extremes in ornamentation of the telson

urchin so closely that when it is hidden in its coral burrow it has fooled even observant naturalists. At such times the spinous, urchin-resembling telson acts as a plug to the entrance of the burrow, effectively concealing the rest of the stomatopod within. The telsons of nearly all, if not all, stomatopods are very characteristically sculptured. Some indeed are unbelievably bizarre in appearance.

A stomatopod larva in season must be the ogre of all the other planktonic crustacean young, for its formidable



Care of eggs by stomatopods. A composite picture showing *Squilla mantis* carrying eggs, and *Gonodactylus oerstedii* tending eggs in coral rock burrow. After Giesbrecht and Brooks

claws do not hesitate to seize anything, even creatures as large as itself. Such was the observation made by Dr. Marie V. Lebour in an aquarium of the Plymouth Marine Biological Laboratory in England.

Once one of 5 mm. was seen to catch a Upogebia larva nearly as long as itself (Fig. 37). For catching such a large animal the chelae come into play and hold the prey tightly between the two terminal joints.

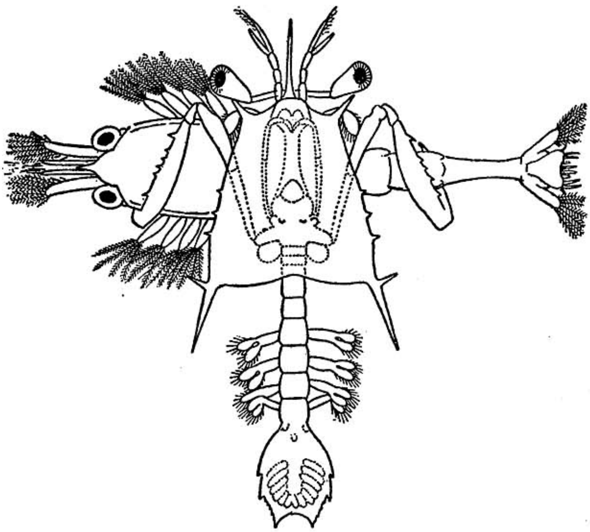


FIG. 37. A larval stomatopod capturing the larva of a burrowing shrimp (*Upogebia*) (x 12). After Lebour

For some time it swam about holding its burden like a baby and beautifully balanced. When first captured the Upogebia was very lively, but soon subsided and died, apparently from intense pressure, but after about half an hour it was dropped and not eaten. Possibly it was too big and had exhausted the Squilla too much. It is certain, however, that the purpose of the chelae is for catching and holding the prey. The Squilla larva always goes towards the light and dances happily up and down with an eager alertness which suggests the constant excitement of capturing live food.

"Like father, like son," certainly applies to the stomatopods, for the adults are unquestionably despoilers of all other kinds of crustaceans. It is not without reason that the wicked and powerful claws of the larva, when fully grown, have earned their possessors the name of "split thumb" in Bermuda and in the West Indies. They are the thugs of crustaceandom, hiding in their runs and warrens by day and consummating their murderous deeds under cover of darkness. Only exceptionally do we find them feeding by day. They can be caught on the coral reef by forcing a sea-cucumber to part with its viscera, a tidbit which seems to have the greatest attraction for all stomatopods. Carnivorous in a high degree, they will eat meat of all descriptions—portions of large crustaceans, crabs, fish, mollusks, worms. They prey upon all available species of shrimp and upon other stomatopods, for cannibalism is not beneath these "racketeers" of the seas and littoral zone. Especially fond of their relatives are they when these are soft and toothsome, in the molting stage. The stomatopods like their soft-shelled crabs as well as you or I. Live fish they catch whenever they get the chance. Sea-anemones are good to eat and are much eaten by the peoples of the Mediterranean region, and some of the stomatopods of these same shores feast eagerly upon them too.

The sharp claws of stomatopods are quite obviously as serviceable for defense as for offense; and to these weapons can be added, if need be, the strong telson spines and the sharp armature of the uropods of all species, which can be lashed out on occasion in all directions by the especially flexible and loose-jointed body. But, as Wilhelm von Giesbrecht quite naturally inquired twenty years ago, against what enemies do these active marauders find it necessary to defend themselves? His inquiry revealed that though some observers had seen various sea-urchins in the act of devouring squillas, it would appear that the victims were either moribund or otherwise incapacitated specimens; for such as were in full possession of their faculties seemed to have little or no difficulty in tearing loose from any of the urchins' tube feet that may have become fastened to them. Octopuses are notorious enemies of crustaceans, particularly crabs, and in aquariums are nothing loath to tackle so porcupinelike a fellow as the stomatopod and to put him away, spines and all, in spite of the repeated blows they suffer in arms and body from the vicious claws and sharp tail spines of the struggling victim. Still, Professor Giesbrecht thought they were not to be reckoned as especial enemies of the active stomatopods.

The late William Keith Brooks wrote of stomatopods;

They are solitary in their habits, and I have never found two in the same burrow. They are pugnacious to an astonishing degree, and their fighting habits, as I have observed them in aquaria, are so fixed and constant that they must be constantly exercised by the animals when at home. When two specimens are placed together in an aquarium they at first appear to be unconscious of each other, but more careful examination will show that their eye stalks are in constant motion following each movement of the enemy. They soon assume a position in which they are face to face, although they may be on opposite sides of the aquarium, and the constant motion of their eye stalks shows how intently each movement is watched. Soon one attempts to get behind the other, but each such attempt is frustrated, until finally they are brought close together, face to face, and soon one springs suddenly upon the other and attempts to pinch some unprotected part. They then spring apart and eye each other again to repeat the attack at short intervals until one is disabled; the other then springs upon him and soon tears him limb from limb, disjointing all the free somites of the body and tearing out and devouring the flesh.

Concerning the care of the eggs by one species of stomatopod, *Gonodactylus oerstedii*, of the Bahamas, he said:

The animal molds or shapes the mass of eggs into a hemispherical cap, which fits over the convexity of the hind body and lies between it and the stone wall of the burrow (Plate 51). The parent reaches out to snatch at passing prey, but so long as she is undisturbed she remains in the burrow. When the burrow is broken open she quickly rolls the eggs into a ball, folds them under her body in a big armful, between the large joints of her raptorial claws, and endeavors to escape with them to a place of safety. The promptness with which this action is performed would seem to indicate that it is an instinct which has been acquired to meet some danger which frequently presents itself. It would seem as if a cave in a solid rock were a pretty safe refuge from all enemies except a naturalist with a geological hammer, and it is difficult to say what the accident is which has thus been provided against. The larger heads of growing coral are often broken off by the waves, and loose fragments of rock are overturned by severe storms, and it is possible that, when alarmed by a violent shock, it flees from its cave to escape the danger of being crushed when the rock is torn from its place and turned over. At any rate its habit is the reverse of that of most burrowing animals, for they usually retreat to the depths of the burrow when alarmed. This is true of all the Stomatopods which I have had an opportunity to observe except this species, and the chief use of the burrow of *Squilla* [*Chloridella*] *empusa* is for refuge in danger, while *Lysiosquilla excavatrix* darts down its burrow at the least alarm and can not be driven out even when the sand has been dug up on all sides of it.

With this we conclude our sketchy survey of the orders of Crustacea. To compress so vast an assemblage into so small a space would be beyond the skill of man, but at least we have, metaphorically speaking, shaken hands with representative citizens of the five subclasses. Further acquaintance with some of their idiosyncrasies may make it easier for us to recognize them again.