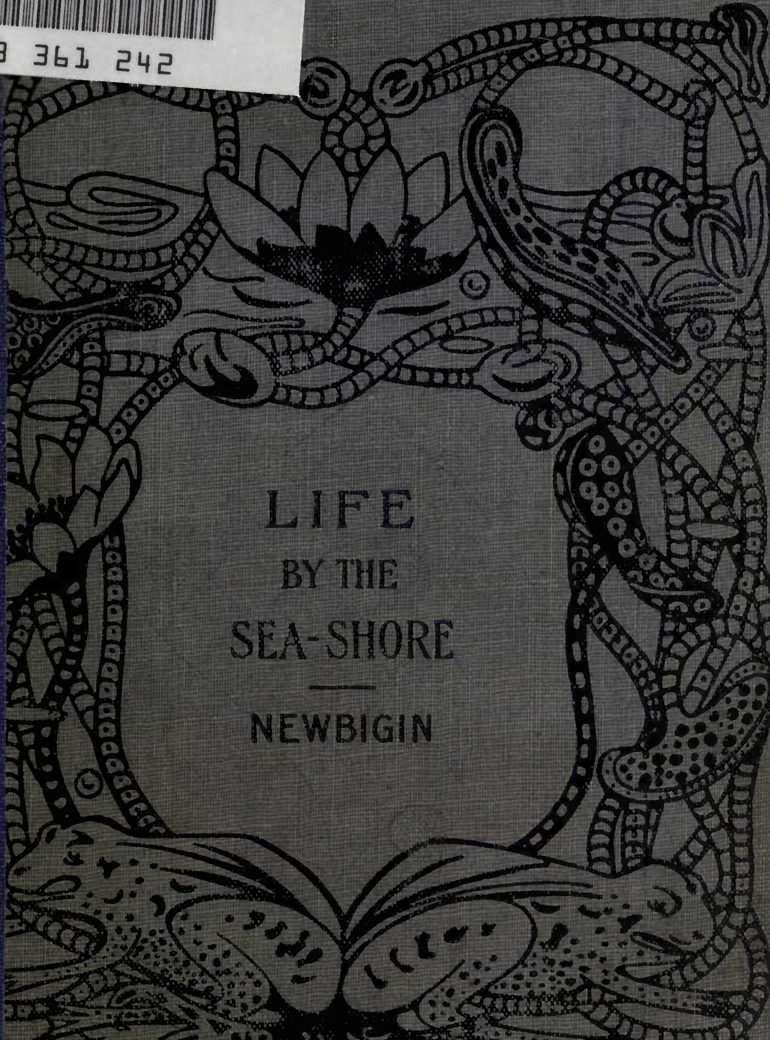

LIFE BY THE SEA-SHORE

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LIFE BY THE SEASHORE

An Introduction to Natural History

BY

MARION NEWBIGIN, D.Sc. (Lond.)

LECTURER ON ZOOLOGY IN MEDICAL COLLEGE FOR WOMEN
EDINBURGH

AUTHOR OF "COLOUR IN NATURE"

WITH MANY ORIGINAL ILLUSTRATIONS BY

FLORENCE NEWBIGIN

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SOME OPINIONS OF THE PRESS

"This little book is quite up to date, and although scientifically accurate and sound, is so delightfully simple that it can be read and comprehended by anyone at the seaside who can collect common shore animals and compare them with the printed pages. It is a pleasure to cordially recommend *Life by the Seashore* as a charming and useful holiday companion, which will not only give much information, but will also serve as a good introduction to one of the most fascinating branches of modern science."—*Nature.*

"The present work can safely claim to have justified its appearance, for it is an exceedingly well written, and as far as it goes a very accurate account of the majority of the common animals found between tide marks."

Journal of Queckett Microscopical Club.

"This is a good book. After reading even the first chapter, one feels that Miss Newbigin knows and cares about her subject. The style and arrangement of the book are excellent; there are numerous illustrations, and at the end of each chapter are tables of classification and a note on distribution which should prove extremely useful."—*Science Gossip.*

"As an introduction to natural history it is admirable, and as a companion to a summer holiday by the sea it is invaluable."—*Weymouth Journal.*

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PREFACE

THIS book is largely based upon a series of lectures on common shore animals, delivered at different times to various audiences. Its object is to enable those who have not had a special zoological training to learn the names and characters of the common inhabitants of the rock pools; but it is hoped that the subject has been treated from a sufficiently broad standpoint to render the book also of value as a general introduction to one of the most fascinating branches of modern science. Special efforts have been made to render the descriptions sufficiently detailed to ensure the identification of actual specimens, and to assist the process by keys and tables. As this detail naturally limits the number of species it is possible to discuss, the book makes no attempt at completeness. It treats chiefly of the common shore forms of the East Coast, but this partiality is corrected, first by notes on distribution, and second by a list of books of reference, which will enable those interested to pursue the subject further. In regard to this list I may say that it has been limited to works in the English language, and to those readily accessible in the public libraries of our larger towns.

As to the difficult question of nomenclature, I have in each group employed the names used in some standard work, indicated in the list of books of reference. Where these names are out of date a reference is given to a source from which the modern terminology can be learnt. Unless such valuable books as Gosse's *Sea-Anemones* are to be rendered useless to the beginner, this seems the only possible course in a popular book.

The figures, which I owe to my sister Miss Florence Newbigin, have in many cases been drawn from actual specimens; the source from which the others have been obtained is indicated in the list of illustrations. To my sister I am also indebted for the Index.

MEDICAL COLLEGE FOR WOMEN
EDINBURGH, *June*, 1901

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LIFE BY THE SEASHORE.

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THERE are perhaps few localities where the extraordinary abundance of life is more striking than on the seashore. From the birds which circle and cry overhead to the countless myriads of sand-hoppers which spring up at every footstep, there seems to be life everywhere, life in a careless and wanton profusion the secret of which is known to the sea alone. Nowhere else does one find animals in such number and variety within a limited area. It is therefore all the more remarkable that while so many people take an interest in terrestrial animals, such as insects and land shells, relatively so few are interested in marine animals, where the field is so much wider, and the phenomena so much more striking. For every person who could name a common anemone there must be dozens who could name a common butterfly, and this in a country not a little proud of its encircling ocean. The opportunity for shore-hunting is nowadays given to very many people for at least a few weeks in every year, and even in this brief time it is possible to acquire not a little knowledge of the ways and structure of the common shore animals.

We shall not at present seek strictly to define the meaning of the word "shore," but in beginning a preliminary study of the conditions of shore life, may conveniently start from that commonplace of observation, which shows that all parts of the shore area are not equally productive. It is true that wherever the ebbing tide leaves bare long stretches of sand, there will be found some of the inhabitants of the littoral waters, living or dead, according to the force of the waves which have torn them from their rocky homes; but we all know that to find these animals in their natural conditions we must forsake the sandy beach for the weed-covered rocks. In order to understand why it is that the majority of shore animals live in the vicinity of rocks, let us watch what happens when some change of current uncovers a ridge of rock hitherto concealed by the sand. We find that the first organisms to appear are usually Algæ of various kinds, the coarser kinds being often the most obvious at first. Then come acorn-shells and vegetable-eating Molluscs, and as these thrive and multiply they are followed by carnivorous whelks, buckies, and starfishes. As the weeds grow, crabs and other Crustaceans make their appearance, and the new settlement thrives apace until it contains most of the animals inhabiting the parent area. How the animals reach the new area is a question to which we shall return later; our special concern now is what determines the gradual colonisation, and why does it only occur where there is a solid substratum of some kind? The answer is simple; it is essentially a question of food, and the food upon which shore animals depend is most abundant in the vicinity of rocks.

Let us for a moment consider generally the food-supplies of marine animals. The simplest case is probably that of the *pelagic* animals, or those animals which live in the open waters of the sea. These all depend ultimately either upon the microscopic plants with which the water is filled, or upon microscopic animals which because they contain green colouring matter are able to feed like plants. The dependence is *primary* when, as in many pelagic worms, molluscs, and sea-squirts, the minute plants are actually taken as food; it is *secondary* when, as in many fish, the food consists of the worms, molluscs, sea-squirts, etc., which themselves feed upon the Algæ. Abundantly supplied with air and sunlight, the little plants grow and multiply rapidly, and constitute the great basal food-supply of the animals of the open sea.

Many of those minute plants, or plant-like animals, occur also in the shallow shore waters, and there again constitute an important part of the food-supply, but this is supplemented in two ways. First, we have an enormous amount of material carried into the sea by rivers. It is a fact of common experience that mudbanks of varying size usually occur about the mouths of rivers. The constituent mud is brought down by the river, and it contains an abundant supply of nutrient material, of which very many shore animals avail themselves. Second, we have the large fixed seaweeds, which can flourish only in water shallow enough for the light to reach them, and which occur in great variety and abundance around our shores wherever there are rocky surfaces to which they can affix themselves.

According to their diet we may divide the shore animals into three sets: (1) those which are vegetarian in habit, living upon the large seaweeds; (2) those which feed upon minute food-particles contained in the water or in sand and mud; (3) those which are carnivorous and depend upon the two preceding sets for food. All these three sets find food most abundant in the vicinity of rocks. The first obviously do so because the large seaweeds grow well only when fixed to a solid base. It may not be quite so clear why the statement is true of the second set, but it is a fact that shore animals which feed on microscopic particles are sedentary animals, not capable of resisting by their own activity the force of shore currents and shore waves. In consequence they usually cannot flourish unless, like the shore weeds, they have a firm basis of attachment. The chief exception arises in the case of burrowers which often live in sand quite away from rocks. As the carnivorous animals depend upon the preceding two sets, it is obvious that they can abound only in the vicinity of the rocks haunted by these. A little experience on the shore will soon convince you that shore animals are not quite so sharply differentiated from one another as regards food as this description seems to suggest, for some forms seem to indulge in a mixed diet; but at the same time it may be helpful at first to look at the food-supply in this way.

So far we have seen that the shore area is above all distinguished by its abundant food-supply, but it must not be supposed on this account that life within this area is necessarily easy. It is indeed rather the reverse that is true. In the first place the abundant food-supply has led to a great increase of population, and a consequent increase in the intensity of the struggle for existence among the shore animals, and in the second place the physical environment is so variable as to make heavy demands on the adaptability of the organism. Look at the wreckage which almost every tide strews upon the beach, and you will realise how fierce is the struggle against inorganic nature which goes on in the shore area.

Let us look for a little at the special peculiarities of the physical environment of shore animals. Round our coasts one of the most striking of the natural phenomena of the littoral region is the daily ebb and flow of the tide. Twice in each twenty-four hours the waters retreat and leave bare a great stretch of the shore, twice they return, the breakers thundering on the rocks as they advance. As everyone who has had anything to do with the sea knows well, not only does the extent of the rise vary according to the locality, but for the same locality it varies from day to day. Twice in every lunar month occurs the phenomenon of spring tides, when the water rises to an unusual height and sinks to a correspondingly low level. Even these spring tides are, however, not constant, certain tides in spring and autumn rising to a much greater height than the ordinary springs. Later, we shall discuss the importance of these facts to the naturalist, at present we are concerned merely with their importance to the shallow-water animals. The shore area is populated by truly marine animals from high-tide mark downwards; indeed, certain periwinkles seem to live above the level of all but the highest spring tides. If we begin with these hardy forms and pass downwards to the region which is uncovered only at the lowest springs, we find a complete series of gradations in regard to exposure to air. The periwinkles mentioned are really under water only for a brief period daily, during perhaps a few days every six months. Then we may have other forms which are covered by water only for a short time at spring tides, and so on down to the animals which are *un*covered only for a brief period during the very lowest springs. But, as all seafaring people know, the times and heights of the tides as indicated in the calculated tables are in many localities liable to considerable variation on account of winds and storms, so that one must beware of ascribing too great constancy to tidal movements. All the animals which belong to the shore area, with a few exceptions which need not concern us here, breathe air dissolved in water, so that the fact that they are periodically exposed to the action of the atmosphere, necessitates special means of protection for the delicate breathing organs. The amount of protection required must necessarily vary with the amount of exposure.

The risk of injury to the breathing organs is not the only danger to which the ebb of the tide exposes shore animals, for the removal of the water makes feeding impossible to not a few of them, and it also exposes them to variations of temperature—the frosts of winter and the sun of summer—and to the keen eyes of the birds which flock to the rocks as the tide ebbs. Furthermore, as the water returns its waves batter furiously against the rocks and their denizens, so that these have manifold dangers to guard against.

Among the general characters of shore animals we should thus expect to find that they usually possess some means of protection against the risk of exposure to the atmosphere, with the correlated risks of freezing or drying up, and also against the force of the waves, which tend to tear them away from their rocky homes. In point of fact, we do find that shore animals show many adaptations to these conditions of shore life. In the first place, very many of them possess shells into which the animal can retire, and which serve to protect it against variations of temperature and the risk of drying up. Shells are especially characteristic of the greater number of the Mollusca, or "shellfish" *par excellence*, but are also possessed by not a few other animals. Thus some worms, like *Serpula* and *Spirorbis*, make white limy tubes and shells into which the whole body can be retracted. The acorn-shells, which are often the commonest of all animals on the shore rocks, are Crustacea which secrete a limy shell into which the whole animal can be withdrawn, and which can then be closed to prevent evaporation of moisture. In these cases, however, the animals are completely sedentary, never moving from the place where they have settled down in youth, and from their size and shape offering little opportunity to the waves. It is otherwise with the Molluscs, which frequently possess considerable power of movement, and have, as it were, to consider both the necessity of protection from drought and from the destructive force of the breakers. We are just beginning to understand the significance of the shapes of shells considered from these points of view, and some of the more obvious adaptations only can be pointed out here.

Most of the molluscs of the shore have either a shell composed of two valves, like cockles, mussels, and their allies, or have univalved shells like limpets, periwinkles, and whelks (Gasteropods). Among the latter the limpet represents the simplest though perhaps not the most primitive condition. Its shell is simply conical, and protects the dorsal region of the animal only; but as everyone knows the limpet has extraordinary clinging power. The thick shell prevents loss of water by evaporation, the firm attachment prevents dislodgment by the force of the waves. The majority of the univalved Molluscs on the shore differ from the limpet in possessing a spirally coiled shell, which is often exceedingly thick and dense, and into which the whole animal can be withdrawn. Such forms as periwinkles, whelks, tops, dog-whelks and others do not cling like the limpet, but when alarmed or attacked often drop suddenly from their attachment. As they do so they withdraw completely into their shells, and close the opening behind them by a shutter, or operculum, which exactly fits the orifice (see Fig. 70, p. 244). This done, the animal is completely encased and protected from extremes of temperature. The shell is so dense that the breakers do relatively little harm, even though the animals are rolled about roughly enough. It is believed that the shape and the sculpture of the shell are all of importance in giving strength to the shell, and in minimising the danger of rough usage. How successful as a protection the shell must be is demonstrated not only by the great abundance of periwinkles, whelks, etc., on the rocks, but also by the way in which they expose themselves to view when the tide ebbs, braving the dangers of frost and sun.

The Bivalve shell seems on the whole less efficient as a means of protection, at least very few Bivalves live on the rocks in the exposed way in which the periwinkles and dog-whelks do. Some, like the mussels, grow in great colonies in sheltered places, very many live buried in sand, not a few burrow in rocks, but most are very liable to wholesale destruction in storms. As a rule the Bivalves have little power of locomotion; they often spin a mass of silky threads, by means of which they anchor themselves to solid bodies, and which, as in the mussels, may constitute their chief defence against the force of the waves.

Analogous to the habit of shell-making is the process of tube-building, which is carried on by hosts of worms. In most cases the tube consists of an organic substance secreted by the animal, to which are added foreign particles such as grains of sand, or fragments of stone and shell. Among the tube-building worms are the "sand-mason" (*Terebella*), a very common form, *Sabellaria*, a social worm, which builds sandy tubes, and many others. In many cases these tubes must be looked on as chiefly a means of protection against organic foes, but in other cases they are strong enough to protect the animal from the dangers of its physical environment.

By far the most effective method of protection against these dangers is, however, the habit of burrowing. A burrowing animal obtains protection from the waves, save in great storms; it obtains permanent moisture, a more or less even temperature, and finally is safe from the persecution of most organic foes. The list of benefits is so long that it is no wonder that so many different kinds of animals have acquired burrowing habits. We can mention only a few of them. If you stoop under overhanging ledges of rocks, or turn over weed-incrusted stones, you may often see numerous holes in the rock, from each of which a red star protrudes. Touch these stars, and they instantly disappear, ejecting a feeble jet of water as they do so. If by means of hammer and chisel you investigate the rock, you will find that the stars are the breathing-tubes or siphons of a little bivalved Mollusc, called *Saxicava*, on account of its rock-boring habits. The little creature remains permanently within its rocky burrows. When the rock is covered by water it protrudes its red tubes, and through them both feeds and breathes; when the tide ebbs, or enemies threaten, it withdraws the tubes, and is safe. Another, and in some ways an even more interesting rock-boring Mollusc, is *Pholas*, of which one species is common in the soft fissile rock called shale by geologists. While walking over stretches of shale you may often notice that it is perforated by numerous round holes. When the rock is covered by water these holes are filled by a brown fringe, with some superficial resemblance to a sea-anemone. At a touch the fringes vanish like a shot. The shale is very soft, and can be readily pulled up in great blocks, when you will find that the holes are the openings of the burrows of *Pholas*, a white Bivalve, with a shell which gapes widely, and is beautifully toothed and sculptured. In the Firth of Forth, where beds of shale are abundant, the rock is often simply riddled by *Pholas* burrows. Other species of the genus burrow in hard rocks, and are then much less easy to extricate.

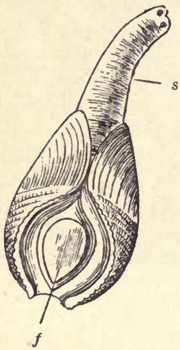

FIG. 1.—*Pholas crispata*, from under surface, to show the foot and the wide gape of the shell. *f*, foot; *s*, siphon.

Far more numerous than the rock-borers are the burrowers in sand, which if it does not form so secure a resting-place as the solid rock is one more easily obtained, and is taken advantage of by many animals. Objection may be taken to the word "many," in view of the fact that children often dig in the sand for hour after hour, and yet rarely come upon a living creature. But the explanation is simple. Animals which burrow in sand almost invariably live on sand; they can therefore only live in sand which is impregnated with organic particles. Such sand occurs usually in the vicinity of rocks or near the mouths of rivers, while in the long stretches of clean sand most frequented by children organic particles are remarkable for their absence. To illustrate the variety of sand-burrowing animals, I may give a list of the spoil taken by a party of which I was a member at some sands in the Firth of Clyde, near Millport. We got first a burrowing sea-anemone (*Pearhia*), any number of heart-urchins (*Echinocardium cordatum*) covered with beautiful golden spines, *Synapta*, a curious pink worm-like creature really allied to sea-urchins, razor-shells (*Solen*), otter-shells (*Lutraria*), old maid shells (*Mya*), all living and active, any number of ringed worms of various kinds, some ribbon-worms, and many sand-eels, and all these occurred together within a very limited area, and were taken in the course of an hour's digging.

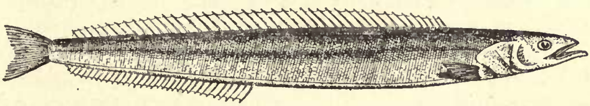

FIG. 2.—Sand-launce or sand-eel (*Ammodytes tobianus*). After Day.

One is tempted to say of each set of marine animals that they are the most interesting of all, but surely there is a special interest about sand-burrowers! The worms, perhaps, one might pass over, for the common earthworm has familiarised us with the burrowing habit, but how does a sea-urchin get deep down into the sand? Those mentioned above were found in one locality, living, not in sand, but in a sandy gravel full of stones and shells. The shell or test of the heart-urchin is as fragile as glass, so thin that unless held with care one's fingers go through it. How does it bore its way among sharp-edged stones without injury? So with many of the others, as the spade turns them up a dozen "hows" and "whys" crowd upon one. Digging in the sand may seem a childish pastime enough, but if you choose your sand aright it has many fascinations.

There are many other of the more sedentary shore animals which do not burrow and are not protected by a thick shell. These usually settle down in damp and dark situations where the sun's rays do not penetrate, or they creep under stones and into chinks and fissures of the rocks as the tide ebbs, to seek protection both from sun and wind and from the keen eyes of the birds. It is in search of these that the shore-hunter diligently turns stones and creeps under overhanging rocks, where the weeds drip and the sea-squirts eject their tiny jets of water. Most of these are protected from the force of the waves by the fact that they are attached and sedentary, or by the shape of their bodies which makes it easy for them to lurk in crevices out of harm's way.

There are still other ways in which shore animals may escape the dangers associated with the ebb and the flow of the tide. Thus they may avoid these dangers by their own activity, following the water as it ebbs seaward, and returning with it when it once more flows landward. These are best represented on the shore by some of the Crustacea—such as prawns, some shrimps, various kinds of lobsters—and by certain fishes. In both cases, however, the power of active swimming is comparatively rare in truly littoral forms, probably because the strong shore currents make it a danger rather than an advantage. Thus, of the shore fishes, the blenny (*Blennius pholis*) remains lurking under stones often quite uncovered by water, the sand-eels (*Ammodytes tobianus*) often bury themselves in the sand, where sticklebacks (*Gasterosteus*) are also at times to be found. Among the shore Crustacea, as we shall afterwards see, there is evidence that in the higher forms the power of swimming has been gradually lost, and the animals have been adapted for life at the bottom and on the tidal rocks. This has been accompanied in the crabs by a modification of the dorsal shield or carapace, which has for its object the protection of the gills from the risk of drying up. So carefully are these protected in many crabs that the animals can live for a long period out of water. In some cases, indeed, as in the common shore crab, an exposure to air during a portion of the day seems actually beneficial. While very many Crustacea and a few fishes are thus rather to be reckoned among the forms which lurk passively in hiding when the tide ebbs, there are still a considerable number who are active swimmers, and constitute the "floating population" of the rocks. The capture of these can only be hoped for when they are trapped in some rock pool by the ebbing waters.

The above brief account of the way in which animals protect themselves against the dangers of their physical environment may serve as an outline which your experience in actual collecting will later enable you to fill up. We may now look for a little at the ways in which the shore animals protect themselves from their organic foes. In some cases, as we have already seen, the same artifice which protects an animal from the one set of dangers protects it from the other. The fisherman's lob-worm (see Fig. 10, p. 30) is greatly relished by very many fish; we can hardly doubt, therefore, that it is, in an ordinary way, protected against these by its burrowing habit. Most tube-worms vanish into their tubes instantly at the least alarm, often merely at a shadow. It is reasonable to conclude that the tube affords a natural protection. It is not very uncommon on the shore to find mutilated whelks, which have apparently had their anterior region bitten off by fish before they had time to withdraw into the shell; a fact which again suggests the protective value of the shell. Facts of this kind might be multiplied indefinitely, but the protective value of hard shells is in the general case sufficiently obvious, and we may pass on to less familiar means of defence.

Many shore animals seem to be protected by their weapons, whether of offence or defence, or by some unpleasant attribute. Thus the great pincers of crabs and lobsters make them dangerous adversaries; jelly-fish and sea-anemones are protected by their stinging-cells; sponges are often full of sharp spicules; many worms have an elaborate armature of bristles; and so on. The power of self-mutilation, or autotomy, is also widely spread among shore animals, and must often assist their escape. Most of the shore crabs, if seized by a limb, will throw off the limb and escape. Brittle-stars break their rays at the slightest touch, and the separated portion keeps up active movements for some time. Not a few "worms" throw off gills or tentacles or other portions of the body when molested. In this case the separated organs move about even more actively than when attached, and doubtless distract the attention of the enemy. In all cases where autotomy is practised, the animals possess the power of renewing the parts thrown off. Almost as curious as self-mutilation is the habit of "shamming dead," which is practised on the shore by many Crustacea, just as it is on land by many insects. Sand-hoppers and the common shore crab may be mentioned as artists in this subterfuge. The habit doubtless saves them from the attacks of animals which confine their attention to moving prey.

Again, not a few animals seek safety in the companionship of other stronger and better protected animals. Examples of this are abundant on the shore. Thus the common hermit-crab often shelters a worm (*Nereis fucata*) within its shell, which no doubt finds the hermit's claws and borrowed house a protection against some foes. The hermit-crab of the West carries about with it an anemone (*Adamsia*) which throws out a quantity of stinging threads, and thus perhaps protects the hermit from attack, while the common hermit-crab often has its shell covered by a luxuriant growth of possibly defensive zoophytes.

FIG. 3.—Hermit-crab with the shell covered by a zoophyte colony (*Hydractinia echinata*). After Allman.

A pretty little Bivalve (*Modiola*) lives habitually within the tough tunic of sea-squirts, while a still more enterprising little Crustacean actually lives inside the body of the sea-squirt. Within the shells of the horse-mussel and some other Bivalves, there may be often found a little soft-shelled crab, which finds there the protection its soft coat cannot give. These are only a few examples of partnership or symbiosis, which is a common phenomenon among shore animals. It is very apt to degenerate into parasitism, where the one partner not only gets house room, but actually lives upon the host.

We have seen that the shell of shellfish affords an apparently efficient protection against many dangers, but it is important to note that not a few Univalves have entirely lost their shells. These constitute the forms known as sea-slugs, sea-lemons, and more generally as Nudibranchs, or "naked-gilled" forms. Many of these occur on the shore, and though on account of the absence of any means of protection against drought they are confined to the zone near low-tide mark, yet there they are abundant enough. Many of them are very brightly coloured, and most are furnished with little processes, either simple or branched, which decorate the back, and add greatly to the beauty.

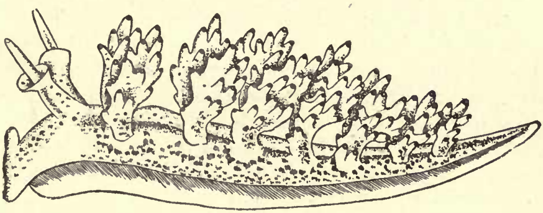

FIG. 4.—*Doto coronata*, a sea-slug with the back ornamented with curious branched processes. After Alder and Hancock.

In spite, however, of the frequent conspicuousness of the animals, and the absence of any protective shell, there can be no doubt that they are very rarely attacked or eaten by the other shore animals. Many naturalists believe that the bright colours and conspicuous processes are an advertisement of inedibility, like the vivid colouring of some inedible caterpillars. It is interesting to note, on the other hand, that while many Nudibranchs are conspicuous and highly coloured, others are exceedingly like the weeds and corallines among which they live. Thus *Doto coronata* (Fig. 4), a beautiful and not uncommon sea-slug, is very like the common coralline, or pink limy weed, and is exceedingly difficult to distinguish from the coralline. There seems no reason to believe that such "protectively" coloured forms are edible any more than the conspicuous forms, and they do not attack active prey; so that the use of the particular coloration does not seem very clear. It is, however, certain that a close resemblance between organism and surroundings is a very common characteristic of shore animals, and doubtless often conceals them from their enemies, and enables them to steal unperceived upon their prey. In not a few cases the coloration is variable, changing with the surroundings. As groups in which this phenomenon may be looked for we may mention Crustacea, such as crabs, shrimps, and their allies; fishes, such as flounders, plaice, etc.; and even anemones, such as the "cave-dweller" (see Fig. 25), *Sagartia troglodytes*, whose colour varieties seem to show a relation to its surroundings.

In connection with this same subject we may notice the habit of "masking" themselves which is displayed by many Crustacea. Practically all the different kinds of spider-crabs are found to have the back and legs covered by a more or less thick coat of weed or zoophytes. These are actually attached by the crabs themselves, as may be readily seen in captivity, and are fastened on by very curious hooked hairs with which the bodies of the crabs are covered. The common *Hyas araneus* (see Fig. 55) of the East Coast may be specially mentioned as a spider-crab which goes about elaborately masked. Another form, *Inachus dorsettensis*, which lives in deeper water, shows a decided preference for sponges, and is often found with back and legs covered by masses of it. Curiously enough, the sponge itself often has its interstices filled with the muddy burrows of a little Crustacean (one of the Amphipods), which is at times present in great numbers.

These cases of "masking" pass by insensible gradations into true *symbiosis*, where there is a constant association between two animals, as in the cases noted above.

There is one danger to which shore animals are subjected which we have not as yet noticed, because although doubtless they have acquired means of protection against it, yet the adaptation is physiological, that is, a matter of function, and cannot be studied as readily as a morphological or structural characteristic can be. This is the danger associated with a possible influx of fresh water into the shore area. In most cases where the shore is fringed by a long stretch of rocks, these rocks are interpenetrated by fresh-water streams, and the animals in the neighbourhood of these streams are liable to be overwhelmed by floods. On a larger scale, rocks in the vicinity of rivers are similarly liable to the influx of large bodies of fresh water. As is well known, many fish are not only indifferent to the contact of fresh water, but at the breeding season actually court it. Among those which can alternate from fresh to salt water without danger are the salmon, eels, sticklebacks, and others. Not a few fish, again, are extremely sensitive to the action of fresh water, which seems to produce an almost instantaneous paralysis. Among the lower animals a good many of the Crustacea and some shellfish or Molluscs haunt estuaries or the neighbourhood of streams, and are indifferent to the presence of a considerable amount of fresh water. In the vast majority of cases, however, especially in the case of animals without shells, fresh water acts as a powerful poison. This is especially interesting, because we know that the salinity of sea water varies greatly; thus the Mediterranean is very dense, while the Baltic contains a very much smaller portion of dissolved salts, and yet some animals inhabit both areas. Experiment shows that while an animal will not support direct transference from one of these media to the other, it can be gradually educated to do this, if the changes are made sufficiently slowly. Part of the interest of the shore area is that it affords constantly varying conditions of life, the variations under ordinary circumstances being small enough to allow the animals time to adapt themselves to the new conditions. It is because of these constant variations that evolution has proceeded so rapidly in the area.

One other general point must be considered, and that is the way in which the animals of the shore area are distributed. In the preceding pages some attempt has been made to indicate the vicissitudes of shore life, and to suggest the great variety of conditions which may prevail there. One consequence of this is that particular shore animals are often very local in their distribution. Obviously an animal which is adapted for life in mud must be confined to areas where mud-beds occur, and thus be absent from long stretches of shore. But apart from simple cases of this kind, it often happens that an animal whose adaptation to some special condition of life is not very obvious, is yet confined to certain localities, and is absent from intervening places which are apparently equally suitable. Thus the beautiful *Alcyonium* (Dead Men's Fingers) only occurs sporadically between tide-marks, probably in part because it offers little resistance to wave action, and requires peculiarly sheltered spots for fixation. Again, the Plumose anemone (*Actinoloba dianthus*, Fig. 26, p. 73), one of the finest of our British anemones, is on the East Coast at least a very local form, sometimes occurring in great beauty and profusion in one particular spot only in a large bay. Many other examples might be given, but without labouring the point, we may say generally that although it is an advantage for adult shore animals to be firmly fixed, or to be able to offer passive resistance of some sort to wave action, yet it is also highly desirable that they should at some period of life possess sufficient power of movement to enable the species to be carried to fresh localities, and suitable localities may be a considerable distance away from the home of the parents. In point of fact, almost all shore animals produce minute active young, which usually live near the surface, and are eminently well adapted for transport by currents or by their own activity. One of the most interesting subjects of study

FIG. 5.—Dead Men's Fingers (*Alcyonium digitatum*), a colony of small polypes.

on the shore is the life-history of the common animals, and the peculiarities of the young forms. In some cases, as in the sea-firs or zoophytes, there is what is known as *alternation of generations*, that is the occurrence in one life-history of two or more different forms, differently produced. Thus, the sessile sea-fir buds off a little swimming-bell or tiny jelly-fish, which produces the eggs from which new sea-firs arise. As the swimming-bells can move actively through the water, and are also very readily swept along by currents, it must often happen that the eggs are deposited some distance away from the original sea-fir colony. Most worms produce eggs which give rise to minute top-shaped larvæ, which live near the surface of the water and ensure the distribution of the species. Even the sluggish Echinoderms, the starfish, sea-urchins, and brittle-stars, produce minute active larvæ, which present no apparent resemblance to the adult, and are adapted for quite a different kind of life.

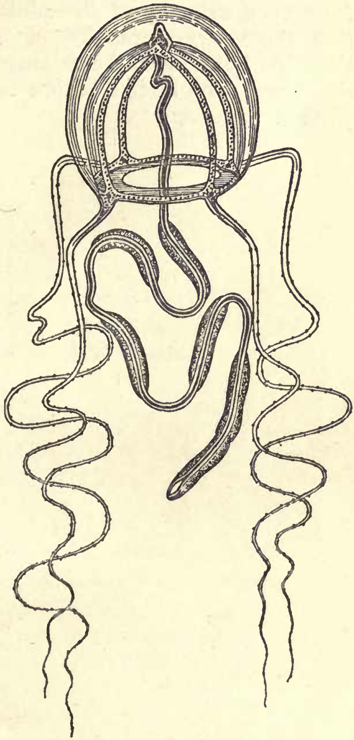

FIG. 6.—Swimming-bell (*Sarsia*) of a sea-fir, showing the long tongue, or manubrium, swollen by the contained eggs, and the four long tentacles which bear stinging-cells. After Allman.

But it is among the Crustacea that we have the most complex and interesting life-histories. In them there is not merely one peculiar larval form, but the young undergo a succession of remarkable changes before they attain the adult form. Our present interest in these cases is due to the fact that the peculiarities of the larvæ ensure the distribution of the species, and compensate for the limitations of that sedentary life which the exigencies of shore life force upon so many of the adults. But we shall see later that these larvæ are also of great interest in possibly throwing light upon the origin of the animals of the seashore, and upon their relations to the animals of the other parts of the ocean.

CHAPTER II.

THE STUDY OF SHORE ANIMALS.

Where to begin—How to begin—The study of common animals—Characters of limpets—Their structure and habits—The common crabs and their characters—Classification of shore animals—General hints as to methods.

WE have in the preceding chapter considered in outline the special nature of the surroundings among which shore animals pass their lives, and the nature of the adaptations by which they respond to the peculiarities of these surroundings. In this chapter we have to consider how the would-be naturalist is to become acquainted with the teeming life of the seashore. The first question to be asked is, Where shall we begin? It is obvious from the foregoing that except where the luxury of a dredge is available the field of action must be the tidal rocks. It is true that the mud-flats at the mouths of rivers and streams may furnish many different worms, some burrowing sea-urchins and sea-anemones, cockles, mussels, and razor-shells; and the streams themselves may abound with shrimps, sand-hoppers, sand-eels, shore crabs, and other hardy creatures; yet, alike for accessibility and for wealth of types, the rock pools claim pre-eminence, and it is with them that it is advisable to begin.

It is probable that the question, Which rocks? will often be determined by other causes than the naturalist's predilections, but it is nevertheless worth while to point out what conditions are especially favourable. For my own part I should be inclined to regard as the most important requisite that of ready accessibility. Where pools of considerable depth are within easy reach of the shore, the observer may hope for a tolerable harvest of some kind. There is undoubtedly great variation in the number, both of individuals and species, obtainable even in places not far distant from one another, and this is especially true in regard to the wreckage flung upon the shore. It not infrequently happens that the set of the current brings treasures to one perhaps small area of a bay, which may elsewhere yield little or nothing even to careful and long-continued search. To those beginning the subject, however, these waifs and strays must rank second to living forms whose habits may be watched from day to day, and for these we must seek the rocks. A famous horticulturist once said that the best advice he could give the amateur was to like what he could grow, if he couldn't grow what he liked. Similarly, the shore naturalist may be advised to interest himself in the animals he finds, if he cannot find those in which he is interested. There are few rocks so barren as to yield nothing to the industrious hunter, and in the general case the statement that a particular area is unproductive, and its pools void of life, is more likely to be based upon inefficient observation than upon fact. Hopefulness is indeed justified even where the surroundings seem adverse in the extreme. I have found brilliantly coloured specimens of the sea-anemone, *Anthea cereus*, in company with many Nudibranchs and rare Annelids, on rocks which I was assured on good authority were hopelessly poisoned by drainage from lead mines. In the Firth of Forth colonies of *Alcyonium* in perfect health and beauty may be found within a few yards of a shore piled with the accumulated nastiness of our civilisation, and similar examples might be multiplied indefinitely. Nevertheless, as a slight guide to those whose choice of a summer resort is unhampered, a brief list of places famous for their shore animals is given at the end of the chapter.

While, however, we recognise in this way that there are few patches of rocks which are not worth a hunt, it is well also to consider under what conditions there is likely to be "good hunting." In the first place it is important to realise, what we have already dwelt upon, that few marine animals like the full glare of the sun, and fewer still the danger of drought. Now the tide ebbs and flows twice a day, and with a spring tide the water may drop a vertical height of up to forty feet; so that it is obvious that unless the moisture-loving animals can allow for the periodic movement of the waters, they must be very liable to elimination either by direct drying up, or by exposure to the keen sight of the birds who follow the receding waves. So far as we know, the tide has always ebbed and flowed, wherefore the shore animals have had time to learn their lesson. The result is that sedentary animals—like sea-anemones, sea-squirts, Alcyonarians, sea-firs, and the like—establish themselves only under overhanging rocks or in deep crevices where, even when the waters retreat, there is a grateful coolness and moisture, and a refuge from keen eyes. Sluggish forms, like many Annelids, the ribbon-worms, the starfishes and brittle-stars, sea-slugs, and many more—which are equally unable to follow the water, and equally unwilling to be deprived of moisture—creep into similar situations or under stones and weed, to pass their time of waiting; and there are left exposed a few hardy forms only, with some special means of minimising the risk of drying up. Finally, at every tide, but more especially at the springs, certain active forms are prevented by untoward circumstances from escaping with the ebbing water, and are held prisoners until it comes again.

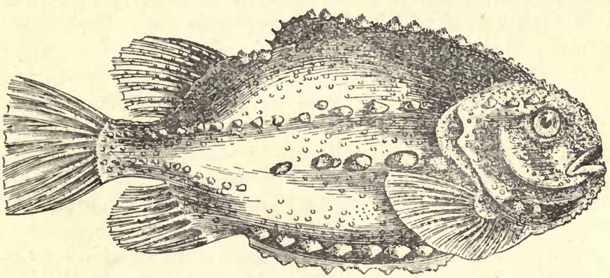

FIG. 7.—Lump-sucker (*Cyclopterus lumpus*). After Day.

Among such are many fish, lump-suckers, gobies, stickle-backs, sea-scorpions, and others; at certain seasons of the year the large cuttles, various Crustacea, and many other curious creatures. If these facts are borne in mind, it will be obvious that rocks are most likely to yield a rich harvest when they are deeply fissured and hollowed out, leaving many shady corners and deep pools; for in the former the sedentary forms will be found, while the latter act as traps to the floating population. It is not, however, sufficient that pools and fissures should exist: there must also be ready access to them. In the case of stratified rocks readiness of access depends largely upon what geologists call the dip. The ideal case is, perhaps, that where the rocks run out to sea in long ridges of which each stratum overhangs its neighbour, while between successive ridges are long channels whose contents are available until the tide actually covers the ridge. When, on the other hand, the rocks dip outwards to the sea, these same channels form dangerous pitfalls to the too enthusiastic naturalist, who lingers on the distant ridges regardless of the eddying currents which are cutting off his retreat. This danger is sufficiently real to make it decidedly worth while to take a general survey of the rocks, and study their peculiarities before beginning serious work.

This done, there still remains one more point to settle, and that is the part of the rocks to which our energies are to be devoted. Broadly speaking, there are two possibilities —the strictly littoral rocks, those which are exposed at ordinary low tide, and are only *completely* covered for a relatively brief period about the time of high tide; and the Laminarian zone, which is only accessible for a short time at extreme low water during spring tides, and then only in part. It is in the pools sheltered beneath the long fronds of *Laminaria*, or oar-weed, that the greatest treasures are to be found—the tiny *Eolis coronata*, with its brilliant colouring in blue and crimson; the active *Galatheas*, darting backwards through the pools; the larger Annelids, with their bright pigments and gleaming iridescence, and many others —but the time during which these pools are accessible is woefully brief, and the beginner is recommended to confine himself, at least at first, to the rocks nearer the shore.

Let us suppose ourselves, then, ready to start for an introductory expedition to the rocks. First, as to the equipment, let this be as simple as possible; the danger lies not in collecting too little, but in the general case in attempting too much. According to my experience the average beginner provides himself with numerous buckets or bottles, and arriving at the rocks proceeds to transfer into these all the animals and pretty pieces of weed which catch his eye. On returning home the spoil is placed in some corner until the weary traveller is rested, is then forgotten, and remains neglected until it ceases to be an object of delight, and is finally thrown out by the irate housemaid, the net result to all concerned being usually an impression that the study of marine zoology is associated with odours of a powerful and unpleasing nature. It is impossible to speak too strongly of that collecting instinct which leads people to gather together all that they see, regardless of the fact that they are leaving the world poorer for their neighbours. Wherefore I would beseech the would-be naturalist to think always of him that follows after.

If the mere accumulation of specimens be discouraged, the question of how to begin remains unsettled; the oft-repeated advice to study the habits of animals, like many similar pieces of advice, not being of great practical value. The way which is likely to lead in the long run to the best results is probably to attempt first to acquire some knowledge of the commonest forms, and then later to utilise the powers of observation which have been trained in this way in a search for rarities. A detailed study of internal anatomy is in most cases very difficult for those without previous training, but a knowledge of external form is not to be despised, and is readily acquired.

For example, any rocks will probably exhibit even to the most casual observer such animals as limpets, crabs, and various kinds of shrimps. Take the limpets first. The most abundant form will be the common limpet (*Patella vulgata*), but in Scotland or the North of England the tortoise-shell limpet (*Acmæa testudinalis*) is almost as common. Far out on the rocks the transparent limpet (*Helcion pellucidum*) will be found creeping over the great fronds of oar-weed, and so on; the list might be extended to considerable length, according to the locality. Now there can be no better exercise, or more fitting introduction to zoological study, than to choose two or more of these forms, and study them until they can be recognised at a glance. This may seem an easy task, but experience shows that it is not so. At one time, when making some observations on the tortoise-shell limpet, I attempted on several occasions to get assistance in collecting specimens. The result was, however, invariably that I was presented with young specimens of the common limpet, with the assurance that these were exactly the right thing.

The differences are nevertheless well marked. In the common limpet the thick shell is marked with ridges which project at the margin of the shell; in the other the surface of the shell is perfectly smooth, and marked with a beautiful "tortoise-shell" pattern in brown. In the common limpet the inside of the shell is glassy smooth and transparent; in the tortoise-shell it is opaque white, except for an elongated brown mark in the upper part. Between the animals themselves the differences are much more marked, as will be readily seen by putting both into a glass bottle and allowing them to crawl up the side. In the flattened creeping sole or *foot*, in the pendent fringe or *mantle-skirt* surrounding this foot, in the horns or tentacles at the sides of the prominent mouth, there is marked resemblance; but in *Patella* the side of the mantle next the foot is pleated and vascular, forming the breathing organ of the animal, while as the little *Acmæa* moves you will see it protrude in front a single plume-like *gill*. As it creeps up the glass, also, you will notice that its mantle is of a delicate green colour, while that of the common limpet is dull-coloured; the whole animal has also a delicate translucency beside which the common limpet seems coarse and ungainly.

In habitat there is also a marked difference. At low tide the common limpet is found far above the water level, with its shell embedded in a slight excavation of the rock into which it closely fits; the tortoise-shell, on the other hand, is rarely found except in pools. The little pits which the common limpet makes and inhabits, together with its tremendous power of adhesion, must diminish the evaporation of moisture, and therefore diminish the risk of drying up; the thick shell probably also aids in the retention of the necessary water. If you knock a living limpet off the rock you will find that the under surface is abundantly moist, while the specimens which have been knocked off by the birds and left foot upwards seem to dry directly. The tortoise-shell limpet does not fit nearly so closely to the rock, its shell is much thinner, and its tissues more delicate; it is probably for these reasons that it never leaves the pools. It must, of course, be realised that both are true aquatic animals, and that a certain amount of moisture is an essential of existence to both. The difference between the power of adhesion of the two forms is so marked that it can be employed as a means of distinguishing them where, from depth of water or other cause, the characters of the shell cannot be clearly seen. As everyone knows, the common limpet may be dislodged by a sudden and unexpected blow; but if the first attempt fail, the alarmed animal adheres so tightly that a knife is necessary to detach it. The tortoise-shell limpet, on the other hand, can always be removed with the fingers alone. It never reaches the size which the common limpet does, but in specimens of the two forms of the same size the difference in the clinging power is quite distinct.

This description should be sufficient to permit of an easy recognition of the two forms, and they should be studied until eye, touch, and muscular sense are so trained that there is no possibility of error. This may seem a trivial occupation, but some preliminary training of this kind is essential to anyone desirous of acquiring an acquaintanceship with species; and the identifying of species, though now sadly out of fashion, is an occupation which may yield one of the subtlest of pleasures. Of late years so much has been said of variation and its consequences, that not only the general public, but even some zoological students, seem to have an idea that species were something abolished by Darwin, and that the notion that there is constancy and orderliness in nature is a mediæval myth. It may well be that the older naturalists made too much of that constancy, and toiled over their species-mongering until they reduced the organic world to the condition of a labelled *hortus siccus* instead of a living, growing reality; but it does not appear that our gain is great if we swing to the opposite extreme, and inculcate the idea that there is no constancy or definiteness in nature at all. So much of the present-day academical teaching seems to have this result, that I cannot but urge anyone beginning open-air studies to find some time for species work, and for this habits of patient and minute observation are essential. It is necessary, also, to emphasise the necessity for handling specimens freely. The healthy child instinct to touch everything seen is so thoroughly educated out of most people, that they never seem to realise how enormously sense impressions are strengthened when hand and eye work in combination. In studying zoology, therefore, from the first train your fingers.

The preliminary study recommended in the case of limpets may be equally well carried out with the different kinds of crabs. The hard coat of the crabs, which gives perfect consistency to the form, renders them particularly well fitted for the present purpose. On every shore two kinds of crabs are almost certain to be found: these are the common shore crab (*Carcinus mœnas*, see Fig. 49, p. 153), and the edible crab (*Cancer pagurus*). The former on the tidal rocks will be found most in evidence, but small forms of the latter are usually very abundant, especially far out, and those who know where to look will not fail to find examples of quite considerable size. The young of the shore crab are extraordinarily variable in colour—they change, indeed, according to their surroundings—while the colours of the young edible crabs are much more constant, though often quite unlike those of the adult. It is not necessary to discuss in detail the differences between the two forms; there are probably few people who could not recognise an adult edible crab when they see it. Unless, however, your perception of form is much stronger than your perception of colour, you will probably find that the colours variations of the young confuse your judgment, and that you have some difficulty in settling the nature of a handful of small crabs gathered at random. If this is so,

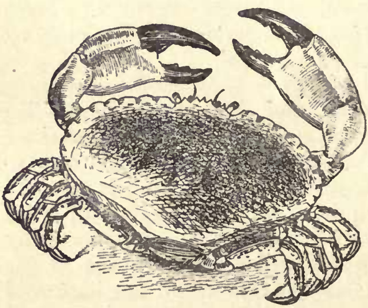

FIG. 8.—Edible crab (*Cancer pagurus*).

the best plan is to take fair-sized specimens of the two forms and compare them point by point. You will notice at once that, just as in the case of the limpets, there is much general resemblance. In all the essentials of structure the two are similar, but there is nevertheless a well-marked difference. Study the two until you can say precisely wherein the difference lies (the shape of the dorsal shield, or carapace, and of the numerous legs will be found especially important), and then return to the young specimens. If your analysis has been careful you will find that the difficulty has vanished, and that you can now sort your specimens without fear of error.

There are many other common animals which can be similarly employed as a means of strengthening the perception of form in animals, and such introductory training will be found of much value afterwards. It will also serve to familiarise you with the haunts and habits of the common types, a point of much importance. As, however, your acquaintance with the rocks and their inhabitants increases, you will find the need of a classification of animals—a method of pigeon-holing your too numerous facts. We shall therefore consider next an outline classification.

The first point to notice is that the fauna of the rocks is so abundant and so varied that, among Invertebrate or backboneless animals at least, there are few great groups which are not numerously represented. The sea, the fruitful mother of all things, retains representatives of most of her children within herself. In spite, therefore, of the fact that our classification is professedly based on marine forms only, we shall find few important blanks in it.

Lowest of all, and including forms with which we shall not concern ourselves much here, are the Protozoa, the primitive unicellular organisms, resembling those from which all others have originated. Consisting as they do of single cells, or of colonies of cells in which the units are not dependent upon one another, it will be readily understood that the Protozoa are mostly minute, often excessively so. Many forms, however, make shells of lime or flint, and may by their abundance give rise to considerable deposits. Such Protozoa helped to form the chalk of the South of England, and are forming the oozes (*Globigerina* ooze and Radiolarian ooze) which are at present accumulating on the floor of the ocean. Protozoon shells may be found among shell-sand on the rocks, but the Protozoon which is most likely to be encountered without special search is the little *Noctiluca*, the chief cause of the occasional "phosphorescence" of our seas. It is just visible to the naked eye, and in the dark appears like a tiny point of light. Into the characters of the Protozoa we shall, however, not here enter in detail.

The next great class of animals includes much more conspicuous forms—the Sponges, long thought to be plants. The familiar bath sponge is, of course, merely the skeleton of a once living animal, or rather of a collection of individuals, a colony of sponges. For an example of a simple sponge you should look under overhanging ledges of rock, and you will find a little sac of dull colour and compressed form hanging downwards. One end is fixed to the rock, the other terminates in an opening which is not a mouth, for nothing enters by it, but which serves as a means of exit for the currents of water which enter the central cavity by numerous pores in its walls. This central cavity is simple and undivided; there is no alimentary canal, and no organs, the sponge is merely a thin-walled sac, lined with cells bearing motile threads or cilia, which by their movement produce continuous currents. Without power of locomotion, with but little feeling, and no active means of defence, the sponges would not be able to survive as they do were it not that they are passively protected by their power of forming a skeleton. This skeleton may be composed of sharp spicules of lime or flint, or of silky fibres, as in the bath sponge, but in all cases it seems to render the sponges ugly mouthfuls, and so induces most animals to let them severely alone. In addition, many sponges have a strong odour. Many are brightly coloured.

The little purse-sponge (*Grantia*), described above, has usually a single large opening, through which water leaves the central cavity; but many sponges, like the bath sponge, or the very common crumb-of-bread sponge found on the shore, have many of these large openings; in the crumb-of-bread sponge they stand up on the flat surface like little craters. As each opening represents an individual, such sponges are really colonies, formed by budding from an originally simple individual. Very many sponges are in this way colonial.

Above Sponges, but still forms of very simple structure, are the Cœlentera, or hollow-bodied animals—sea-anemones, corals, sea-firs, "dead men's fingers," jelly-fish, and many others, almost all beautiful in form and colour, and with a delicacy and fragility which makes it essential that they should be studied in the living condition. They agree with Sponges and differ from higher animals in containing one central cavity only, instead of having an alimentary canal inclosed within a general body-cavity. They have, however, a true mouth surrounded by tentacles, instead of the numerous pores of the Sponges; the skin, especially on the tentacles, contains offensive and defensive stinging-cells which can be ejected; there is often a skeleton of lime or some other substance; their symmetry is *radiate*, like that of a flower. Many of the Cœlentera are colonial, and it is such colonial forms which build up the coral reefs of warm seas.

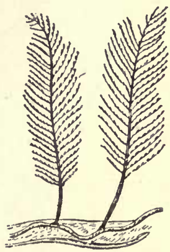

Fig 9.—*Plumularia setacea*. After Hincks. One of the sea-firs.

Above the Cœlentera we come to the Unsegmented Worms, animals not nearly related to one another, but all differing from the Cœlentera in having distinct anterior and posterior regions—a distinction of head and tail, in having a separate alimentary canal within the general body-cavity, which may, however, be largely filled up, and in the greater complexity of their structure. Among these we shall be concerned only with certain little flat-worms called Turbellaria, and with the ribbon-worms (Nemertea).

Much more highly differentiated, but sometimes loosely included under the heading of "worms," we have the Segmented Worms, or Annelids. In them the body is divided into successive rings, or segments, of similar structure, which usually bear locomotor organs furnished with bristles. There is a well-developed body-cavity, which opens to the exterior by little coiled tubes, or nephridia, structures of much importance to the morphologist. The Annelids which are especially adapted for a marine life

(Polychæta), are very numerous, and include many interesting and beautiful forms. To them we shall return at length. They are recognised by the elongated segmented body, and the lateral tufts of bristles.

FIG. 10—Fisherman's lob-worm (*Arenicola piscatorum*). *g*, gills; *b*, tuft of bristles; *p*, partially everted proboscis. A common Polychæte.

The next group, somewhat isolated in position, and not closely related to the foregoing, is that of the ECHINODERMS, or *Prickly Skins*, including sea-urchins, starfishes, brittle-stars, sea-lilies, and sea-cucumbers; marine forms with limy skeleton and radiate symmetry, almost always easy to recognise and classify. They have a peculiar "water vascular" system, which in the common starfish, for example, is connected with the delicate transparent tube-feet, by means of which the animal moves.

The next great class is that of the ARTHROPODS, or animals whose bodies are made up of a series of rings or segments, which are furnished with hollow *jointed feet*. The vast majority of the shore Arthropods are CRUSTACEA, which take on the shore rocks the place taken by the Insects on land. The Crustacea include crabs, lobsters, shrimps, sand-hoppers, etc., animals with two pairs of feelers on the head instead of one pair as in Insects, with a hard, limy coat, and breathing by gills instead of the air-tubes of Insects. There are an enormous number of Crustacea on the shore, where they occupy all zones from high-tide mark to deep water. They are the great scavengers of the sea, for many of them live on dead and putrefying matter. In this respect also they resemble Insects, which are the great carrion feeders of the land.

The last group of Invertebrate animals, or those without a backbone, is the MOLLUSCA, including Bivalves, like mussels, scallops, cockles, etc.; Gasteropods, like periwinkle and whelk; cuttles, like squid and octopus. The Mollusca have soft, unsegmented bodies usually covered by a shell secreted by a fold of skin called the mantle, but many shore Molluscs have no shell. They usually breathe by gills or by the mantle, and have a very characteristic muscular protrusion called the foot, which is usually the organ of locomotion, and is well seen in the garden snail, where it forms the creeping surface.

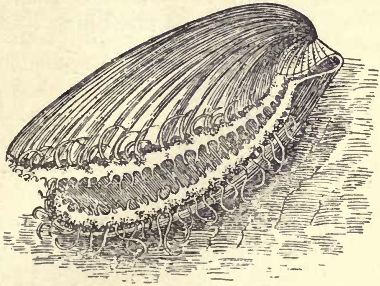

FIG. 11.—Common scallop (*Pecten opercularis*). A bivalve Mollusc.

The Vertebrates of the shore include the FISHES, easily recognised without special description, and the TUNICATES, or sea squirts, a strange set of animals much modified and not easy to recognise. Those on the shore are of two kinds—the simple forms which are little shapeless sacs found under stones and overhanging rocks, and the compound forms which consist of little stars within a sheet of jelly-like substance which spreads over rocks and stones. The simple forms have two openings at the upper end, from which on an alarm they eject jets of water. They are enveloped in a usually tough *tunic*, which can be torn off, and reveals the soft body beneath. Of the details of structure something will be said later.

The outline classification of shore animals just given may be summed up in the following table:—

Invertebrata.

Animals which at no time of life have a backbone or any similar structure down the back. Gill-slits, or openings between the mouth-cavity and the exterior, present in fishes and sea-squirts, are here absent; gills when present are outgrowths of the skin.

I. Protozoa.—Minute, usually microscopic forms, important as furnishing food for higher forms.

II. Sponges.—May be recognised by their spongy, porous bodies, furnished with one or more openings, and containing a skeleton of lime, flint, or horn. The crumb-of-bread sponge and the purse-sponge are common both in the fresh and dried state.

III. Cœlentera.—*Hollow-bodied* animals, including sea-anemones, jelly-fish, sea-firs, "dead men's fingers," and many others. The mouth surrounded by tentacles bearing stinging-cells is a very characteristic structure.

IV. Unsegmented Worms.—The ribbon-worms have lank unsegmented bodies, very uniform throughout their length, and eject a thread or proboscis when alarmed. The Turbellaria are flat and leaf-like, and move with a peculiar gliding motion.

V. Annelids, or Segmented Worms.—The body is divided into rings, or segments, which bear lateral tufts of bristles. Very many live in tubes, and then the bristles may be inconspicuous.

VI. Echinoderms.—*Prickly-skinned* animals, usually with much lime in the skin; the body is more or less star-like, and the delicate, transparent tube-feet are very characteristic. Starfishes, brittle-stars, and sea-urchins are the commonest kinds.

VII. Arthropods.—These, the animals with *jointed legs*, are represented by the *hard-coated* Crustacea—shrimps, prawns, lobsters, crabs, sand-hoppers, etc. —which are very varied in form, but are recognised by the segmented body, the jointed legs, the hard coat, the two pairs of feelers.

VIII. Mollusca.—The Bivalves, such as mussels and oysters and so on, are readily recognised by the double shell. The snail-like forms (Gasteropods) have sometimes a coiled shell, sometimes a conical one (limpet), and are sometimes without a shell. They can be generally recognised by the creeping foot and the horns on the head. The cuttles have many arms bearing suckers. All Molluscs have *soft* unsegmented bodies without appendages.

Vertebrata are represented on the rocks by Tunicates or sea-squirts with their tough tunics, and by the Fishes, which can be recognised without difficulty.

This account should enable even the beginner to fix roughly the position of the common animals of the shore, and is best learnt by repeatedly collecting all the animals found within a given area, say a large pool, and sorting them into their different categories. Such an operation can be readily performed on the shore, and will add greatly to the interest of the early visits to the rocks. It is easy to choose or make a series of little pools which may represent the different classes, then search the rocks in their neighbourhood, returning after each excursion to the pools to place the spoils in their correct position. At first it is well to have an additional reservoir for what the naturalist calls *incertæ sedis.* It is not the least of the pleasures of field zoology to find how quickly the eye becomes trained, how the contents of the "uncertainty pool" steadily diminish as the perception of form increases, and the eye picks out perhaps the one obvious point which settles the position of the animal. Errors are of small moment, for after all there is error in the best and most recent classifications. Few years pass in which it is not shown to the scientific world that some form or other, not always an insignificant one, has been assigned to a wrong position, and the best arrangement is nothing more than an approximation. The point is to draw up a classification which will as far as may be express your knowledge. If it differs from that adopted by other people, this may be due to your ignorance or to theirs —if you but go on you will soon find out which; it is better to make an error and learn that you are wrong than to accept as dogma a classification which means nothing to you.

When practice of this kind has rendered the commonest forms familiar, it is time enough to begin serious collecting. In the following chapters we shall consider the animals of the shore according to their systematic position, proceeding from the simpler forms to the more complex. This method has many advantages from the point of view of the anatomist, and is convenient for reference, but the novice when working with actual specimens will find detailed identifications much more difficult in the case of simple forms like Sponges than in the more complex Crustacea, for example, which are comparatively easy to study. The shore crabs, indeed, make a good starting-point, for they are easily found, easily named, make in many cases most interesting and intelligent pets, and can be very readily studied. As, further, they all periodically cast their coats, and these coats—which are an exact replica of the crab—are always to be found on the beach, they are admirably suited to persons with humanitarian tendencies.

One other point deserves some notice. Very many people are afraid to handle almost any shore animal, because of a general conviction that all bite or sting. They may be reassured by learning that in our seas there are very few dangerous animals indeed. Apart from the true stinging-fish, or weever, there are one or two shallow-water fish, such as the sea-scorpions (*Cottus*), which are furnished with spines strong enough to wound an incautious hand. It is perhaps as well, therefore, not to handle living fish freely till you know something about them. Again, the very large jelly-fish which are sometimes to be found in the pools in autumn, especially those of the West Coast, can sting pretty severely, but with these exceptions almost any animal on the shore can be handled with impunity. It is of course obvious that the large Crustacea should be treated with discretion, for many of them can give a pretty sharp nip; but the widespread fear of being "stung" is quite unjustifiable except in the case of the big jelly-fish and the weever.

Finally, we may note that a tide-table is an important part of the equipment for serious work. This may be obtained either from a Nautical Almanack, or from most of the newspapers published in maritime towns. Collecting is most likely to be successful during spring tides, and should be begun from five to six hours after the time of full tide. In order to assist the beginner, a list of watering-places which have a reputation as offering good hunting-ground to the collector has been added to this chapter, but it should be understood that almost every maritime village offers facilities of some sort. The differences are chiefly differences of degree, and in many cases a place acquires a great reputation less on account of any outstanding merit than because of the patient research of some particular worker, who has given to the world long lists of animals as the results of his shore hunting. It may be well to emphasise the steady patience of such workers, lest the novice make a pilgrimage to one of the places mentioned, and be disappointed at not finding all the treasures for which the place is famous. It should be remembered that lists such as that of Professor McIntosh for St. Andrews (see "Books of Reference" at end) represent years of hard work. We shall indicate subsequently the kinds of animals which may be expected to occur at different parts of the coast, but may note here that at such places as St. Andrews, North Berwick, Dunbar, Alnmouth, Whitley, and Scarborough, the shore fauna has a generally northern aspect. At the very many favourable spots on the coasts of Dorset, Devon, and Cornwall, such as Bournemouth, Poole, Weymouth, Portland, Lyme Regis, Teignmouth, Torquay, Paignton, Falmouth, Penzance, and Ilfracombe, many rare and beautiful southern forms occur. These are also, though to a lesser extent, present at such places as Tenby, Aberystwyth, and around the shores of the Isle of Man; while as we travel further north we find in the Firth of Clyde, *e.g.* at Millport, or on the West Coast, as at Oban, a certain admixture of northern and southern forms, the latter having spread up the warm West Coast.

CHAPTER III.

SPONGES, ZOOPHYTES, AND SEA-FIRS.

General characters of Sponges—Some common Sponges—Characters of the Cœlentera—How to keep them alive—General account of Zoophytes and Sea-Firs—The common Zoophytes and their swimming-bells—The families of Sea-firs—Some common Sea-firs—Comparison between British Hydrozoa and those of other seas—Characters of swimming-bells.

OF the many-celled animals of the shore the Sponges are the simplest in structure, and therefore should logically come at the beginning of an account of shore animals. They are, however, far from easy to recognise and classify, and in most cases the determination of species requires more skill and patience than can reasonably be supposed to be possessed by anyone but a specialist. A large part of the difficulty lies in the fact that sponges have no conspicuous external appendages, and no obvious organs which can be used in classification. The classification must therefore depend upon minute characters, especially upon the nature of the spicules—points which are often difficult to study. We shall in consequence confine ourselves to such an account of British sponges as will enable the student to know a sponge when he sees it, and to be able to name one or two of the commonest forms.

In the first place it should be understood that sponges are purely sedentary animals, so plant-like in appearance that they were long thought to be plants. As in so many sedentary shore animals, the young are minute and active. They settle down in sheltered places under overhanging rocks, on stones, on the broad fronds of weeds, and not infrequently on living animals, especially Crustacea. From the places where they once attach themselves the sponges never move. They feed on minute particles contained in the water, which is swept through the porous body in continuous streams. Most of them bud freely, often forming large colonies which spread over the rocks as lichens spread over trees. With very few exceptions, they all contain a skeleton in the form of fibres or sharp spicules. The colours are often variable and bright, and as a little shore hunting will soon convince you, sponges often have an unpleasant smell; in this respect they resemble the more beautiful sea-anemones, which often give a peculiar and disagreeable odour to the dark caverns in which some species love to dwell. Sponges can generally be recognised by the presence of distinct pores, and the characteristic "spongy" appearance of the substance when torn. In some cases not a little care is required to distinguish them from certain compound sea-squirts, which may contain spicules, and from Polyzoa, or sea-mats, which often contain a large amount of lime, and are occasionally not unlike sponges. Both sea-squirts and Polyzoa, when carefully examined, show the presence of "polypes," of which there is, of course, no trace in sponges.

Without making any attempt to discuss the classification of sponges, we may briefly note the salient characteristics of three common forms.

By far the commonest sponge on the shore rocks is the crumb-of-bread sponge (*Halichondria panicea*), which forms a thick crust, often many inches square, over rocks and stones in all sorts of situations. It seems to grow equally well when fully exposed to light and when sheltered in dark crevices, and though perhaps commonest on a flat surface does also occur on various seaweeds, especially the stems of *Laminaria*, or oar-weed, which are often completely invested by the sponge. There are indeed few spots on the tidal rocks where the crumb-of-bread sponge cannot obtain a foothold. In the dry state it is commonly found on the shore, and such dried specimens sometimes puzzle the beginner by appearing much more "spongy" than the living sponge as found on the rocks. This is due to the partial loss of the soft parts which brings the skeleton into greater prominence. In colour the sponge varies greatly; it is often distinctly green, and at other times shows various shades of yellow, brown, and drab. Dried specimens found on the beach are always colourless. In the living sponge the most conspicuous feature is usually the number of openings or *oscula*, which stud the surface and are raised on little prominences, but in specimens which have grown in a spot where space is limited, as on one of the smaller seaweeds, these oscula are less conspicuous. The surface of the sponge is marked by a distinct network of lines, and when its substance is torn with needles it will be found that it is full of minute flinty spicules.

Another very common sponge is *Grantia compressa*, the purse-sponge already mentioned. It is dull in tint, being greyish brown in colour, and rarely grows in such exposed situations as the crumb-of-bread sponge. It is usually to be found under overhanging rocks with the orifice hanging downwards, and the base attached to the rock surface. It is sac-like in shape, and in the dead state much flattened and compressed. In life, however, the central cavity is full of water, and the sponge is much plumper in appearance. It is of much interest, because it was in it that Robert Grant—after whom it is called—first discovered that in a sponge currents of water enter the central cavity by minute pores, and leave it by the large osculum. These currents can be readily observed in living specimens placed in sea-water containing solid particles in suspension. The sponge differs from *Halichondria* in having a skeleton made of spicules of lime and not of flint, and in being usually simple, whereas *Halichondria*, with its many oscula, is an example of a compound sponge. Occasionally budding occurs, so that there may be as many as seven or eight oscula, but the usual form is that of a slightly stalked sac with one terminal opening. The skeleton, made of three-rayed spicules, may be seen by teasing a little of the sponge substance under a lens, and the fact that it is limy may be proved by adding a drop of dilute acid, when effervescence occurs as in the case of limestone under the same circumstances. The minute pores in the walls of the body are not easily seen except in dried specimens, and even then they are largely concealed by the spicules. The purse-sponge is very common between tide-marks, but is usually only about an inch long, and is somewhat inconspicuous.

A smaller but much more dainty little sponge is *Grantia ciliata*, a delicate silky little creature not usually more than half an inch in length. It is oval in form, of a cream or greyish colour, and has a crown of beautiful spicules round the osculum. It is a solitary form and usually occurs far out on the rocks. When examined with a lens it will be seen that the silky appearance is due to the fact that the surface is covered with prominences, each ending in a long slender spicule. In life the direction of the crown of spicules varies according to the flow of water through the sponge; sometimes they spread outwards in a radiating manner, and at other times they lie parallel to the long axis of the sponge. This pretty little sponge is not very common on the shore, and usually requires to be sought for.

These three examples may serve to give the student some idea of sponge structure; on certain parts of the coast, especially on the South, other species are common between tide-marks, but for these reference must be made to special memoirs.

After the sponges we come to the hollow-bodied animals, or Cœlentera, which include some of the most beautiful of our shore animals. Lovely as they are in life, both in colour and form, they lose practically all their beauty at death, when the majority become mere shapeless masses. In consequence they must be studied in the living condition, and this is fortunately rendered possible by the fact that not a few will live well in confinement. This is, of course, especially true of the sea-anemones, which make charming pets. A few words may be said as to the best methods of keeping the more delicate sea animals alive. Those who have abundance of spare time, much patience, and not a little spare cash will probably take naturally to aquarium-keeping—that is, to the maintenance of tanks containing sufficient growing plants to balance the animal life. Even when all these requisites are present, however, the aquarium is always liable to go wrong, and is never very easy of management except on a very small scale. By far the easiest method of keeping marine animals alive is in flat shallow pans, which expose a large surface to the air relative to the bulk of water present. A common pie-dish of large size does well. It should only be about half full, and at most should contain only two or three small animals. If it is kept carefully cleaned, and has fresh water added to make up for loss by evaporation, it will be found unnecessary to change the water for a very long period. In such a dish many of the shore animals will live well, and there is much more chance that you will really observe the habits of your pets if each one has a dish to itself than if they are placed in a crowded aquarium among many other animals. The points of special importance are: do not crowd, and do not use a vessel which holds a great bulk of water proportionate to the surface exposed to the action of the atmosphere. Some shore animals, such as the common crab, the common limpet, and others, will only live where they are partially exposed to air, and a great number are much more sensitive to impurities in the water than to a partial exposure of their surface to the atmosphere. Finally, in keeping marine animals in confinement, do not forget that the object, as well as the justification of the practice, is that you may observe their habits; therefore do not forget to look at them, to notice their changes, to draw them if possible.

The Cœlentera, or sea-nettles, as the German popular name may be translated, form a very large group, including a number of different kinds of animals. The most obvious common character is the presence of tentacles, which bear the stinging-cells to which the German name refers. Let not the name alarm the sensitive naturalist, however, for, as already mentioned, in this country, except in the case of the jelly-fish and such southern forms as the "Portuguese man-of-war," these stinging-cells will not penetrate our skin. We may begin our study of the group by examining a very delicate and harmless little creature, one of the zoophytes or animals like plants. If you examine the shore pools with a little care, you will find a number of spiral shells lying apparently loose at the bottom, with their surface often covered with a brown or pinkish crust. As you watch, the apparently empty shells will move away with considerable speed, disclosing the long legs of a hermit-crab as they do so (see Fig. 3). Pick out the shell in which the surface crust seems to be best marked, and drop it into a shallow dish filled with sea-water. In a few minutes the hermit will recover his equilibrium, and once more appear on his doorstep. About the same time the dingy crust on the shell will change its appearance, and show you a delicate waving forest of little pink creatures, which spread out in the water

Fig. 12.—Diagram representing the individual persons or zooids in a colony of *Hydractinia echinata.* *a*, nutritive person with tentacles extended; *b*, sensitive person with aborted tentacles; *c*, reproductive persons bearing clusters of sporosacs. At the bases of the persons are shown the stout protective spines. After Allman.

like miniature flowers. The whole crust constitutes a *zoophyte colony*, the tiny flowers are the members of the colony, and are called *polypes*, or better, *zooids.* We have begun our study of the sea-nettles with a colony of this kind, rather than with the more familiar sea-anemones, because the members of the colony show the characteristic sea-nettle shape in perhaps its simplest form. Each zooid, as the figure shows, is like a tiny hollow column; it is fixed by one end to the shell, while the other end, with its crown of tentacles, floats freely in the water. Small as the tentacles are, they still bear stinging-cells, which paralyse the prey caught by the tentacles.

With the help of a lens and patience we can carry our observations considerably beyond this point, and make out that though the little zooids are similar in their broad outlines of structure, there are marked differences in detail. In the majority of the individuals (see diagram) the body is long and cylindrical, ending in a mouth surrounded by twenty to thirty tentacles. These are the "nutritive persons" of the colony, which catch and digest the little particles which constitute the food of the entire colony. Their central cavities are connected with a series of canals which ramify over the surface of the shell on which the colony is placed, and are again connected with the central cavities of the other zooids. By this means the food is conveyed in a digested condition all over the colony. The other zooids are of two kinds. Near the margin of the colony, and overhanging the mouth of the shell, there are peculiar long spiral individuals (marked *b* in diagram), which are extraordinarily muscular and active, but are without mouth and tentacles. The function of these "sensitive persons" seems to be to warn the other members of the colony of the approach of danger. Scattered among the nutritive persons are the third set of zooids (marked *c* in diagram), which are similar to these, but only about half as high, and have rudimentary mouth and tentacles. The special peculiarity of these zooids is that they bear lateral clusters of *sporosacs*, which are oval bodies containing eggs or male elements. In *Hydractinia echinata*, as the zoophyte is called, the sporosacs remain permanently attached to the colony, but in very many of the zoophytes minute swimming-bells, or medusoids, are produced instead of sporosacs, and these swimming-bells float away, and carry the eggs to some more or less distant spot. Finally, in *Hydractinia* there are mingled with the persons a number of spines, which may be aborted persons, and which have some protective function.

From this description of *Hydractinia* a general idea of the character of the Cœlentera may be gathered. The members of the group are usually either polypes, like those of *Hydractinia*, or are jelly-fish, like the swimming-bells of many zoophyte colonies; but both types of structure occur in many much-modified forms. Both types not infrequently occur in the course of one life-history, and then the phenomenon which we have already studied as alternation of generations is produced. Many forms are colonial, like *Hydractinia*, and in such colonies there may be division of labour among the members of the colony.

The Cœlentera are very numerous, and are found in all seas and at all depths; but the different parts of the ocean have their characteristic forms. Thus, as we all know, the reef-building corals are confined to the warm seas, and even in the British area there are far more sea-anemones on the South and West than in the colder waters of the East Coast, while certain zoophytes which occur in the North and East are absent in the South and West.

In studying the Cœlentera we shall begin with the zoophyte colonies, similar to *Hydractinia*, which are so abundant on our coast. Of these, *Hydractinia* is, in one sense, a relatively simple type, for its skeleton is only represented by the crust which covers the shell on which the colony is placed, and by the little spines arising from this crust. In most of the zoophytes the colony is surrounded by a protective sheath, which sometimes forms little cups in which the individual zooids are placed. As the sheath is tough and resistant, it not only keeps the colony expanded during life, but also persists after the death of the zooids. These dead colonies are often flung up on the beach, and are more familiar to most people than the living zoophytes. From their peculiar method of branching they are known as "sea-firs," or are often incorrectly regarded as "seaweed." The first class of Cœlentera, therefore, includes delicate zoophytes, with practically no skeleton, such as *Hydractinia* and many others; the sea-firs, with their resistant coat; the swimming-bells, or medusoids, which arise from many zoophytes and sea-firs; and also some other colonial forms much less common in our seas. This first class is termed the HYDROZOA, and the individual zooids, or polypes, are called *hydroid*, from their general resemblance to the little fresh-water *Hydra.*

Among the zoophytes and sea-firs the character which varies most, and which affords a basis for classification, is the skeleton. Let us first understand what this skeleton is, and what is its function. Both the terms "skeleton" and "supporting substance," which one naturally applies to it, are misleading, because both suggest the idea of support. Now the sea-nettles do not require support for their soft parts, because these can be, as it were, stretched by the water which the animals take into their central cavity. An anemone when extended, *i.e.* when filled with sea-water, is firm and tense; it is only when it ejects this water that it collapses. The main object of the skeleton in those sea-nettles which possess this structure must therefore be to serve as a means of protection. Take our little pink *Hydractinia*, for example. When alarmed the zooids contract and cower down among the spines, so that an inquisitive foe darting at the floating pink things will find them lost among these hard inedible thorns. Again, look at any of the common sea-firs so frequent on weed. The tiny branches are crowded with zooids, possibly edible enough, but each of these is placed in a little cup of horny matter. When alarmed they withdraw into the cups, and a persevering enemy is likely to get a maximum of indigestible horn, and a minimum of digestible zooid. Zoophytes and sea-firs are extraordinarily numerous on the shore rocks, and in most cases they are protected to a greater or less extent by a horny skeleton.

In the minority the skeleton is represented either by a mere plate at the base of the colony, or by tubes which envelop some part of the columnar body. In these naked forms (Gymnoblastea) the individuals are often large and highly coloured with numerous conspicuous tentacles. In the majority of the shore forms the skeleton is greatly developed, and carries little cups, in which the zooids are placed, and into which they can be completely retracted. In this set, called Calyptoblastea from the cups, the individuals are small, but usually very numerous, and the skeleton is the most conspicuous part of the colony.

We shall mention the salient characteristics of a few of the commonest naked zoophytes; for such detailed description as may render the recognition of actual specimens possible, reference should be made to the tables at the end of the chapter.

In *Hydractinia* we have already described a zoophyte in which the skeleton is very slightly developed, but there is another pretty form in which there is even less horny matter. This is the club-shaped zoophyte (*Clava squamata*), often exceedingly common between tide-marks. If in shore collecting you are endeavouring to throw back the heavy dripping curtains of bladder-wrack, which hang pendent in front of the great rock-clefts, you may often notice little pink fleshy spots on the weed. Insignificant enough they look, but it is well worth your while to break off a bit of the weed and drop it in a clear pool. You will then find that the fleshy mass is a dense cluster of short stout zooids, which soon unfold in water and display their characteristic club-shape (see Fig. 13). Each bears numerous scattered thread-like tentacles, and at times, in addition to these tentacles, one finds that the zooids have a distinct collar made up of little beads. These are clearly shown in the figure. Each bead is a sporosac, containing eggs, which grow directly into fresh colonies. The individuals may reach a length of about an inch, but the colonies never contain very many individuals. There is no skeleton save a slight attaching plate on the weed.

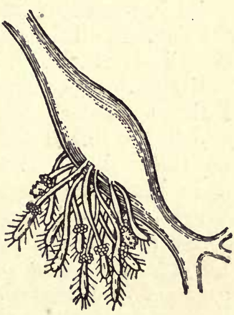

FIG. 13.—*Clava squamata* on weed. After Allman.

As the next stage in the development of skeleton we may mention *Hydractinia* where we have the spines in addition to the basal plate. It is also remarkable because of the fact that, as already mentioned, the colony includes three different kinds of individuals. This "polymorphism," or occurrence of more than one form, is rare among the Hydrozoa of the shore, though it commonly occurs among those of the open sea, *e.g.* in the "Portuguese man-of-war" of the South Coast.

In the next zoophyte to be mentioned we find that the skeleton forms tubes in which the zooids are placed, much as a worm lies in its tube. In examining the more delicate kinds of weeds on the shore, a quick eye will often pick out small yellowish tubes branching among the weed, and bearing small zooids with numerous scattered tentacles, remarkable in having a prominent knob at their tip, whence they are called capitate. These zoophytes are species of *Coryne* and *Syncoryne.* Without going into the characters in detail here, let us notice one interesting point in regard to the reproduction. In all the zoophytes described as yet we have noticed the occurrence of little sporosacs, structures which lie like little fruits on the wall of the body, and bear the eggs from which new colonies arise. These are present again in *Coryne*, clustering at the bases of the tentacles, but in *Syncoryne*, although the same little fruits are to be seen, they do not set free eggs, but tiny bells of jelly, which swim away through the water with a gentle pulsating movement. After being set free the bells undergo various changes, and become converted into swimming-bells, or medusoids, called *Sarsia* (Figs. 6 and 15), often found near the surface of the sea in autumn. They, together with many other medusoids, may be caught by sweeping the surface of the rock pools or the open bay with a fine net on a calm day. Any medusoid resembles more or less exactly a bell in shape, with a stalk or manubrium hanging down in the centre to represent the clapper. We must, however, suppose the upper part of the bell to be much thickened, for it consists of a mass of transparent jelly, which fills up, as it were, the upper part of the hollow of the bell. Further, the mouth of the bell is largely filled up by a transparent shelf which projects inwards from the

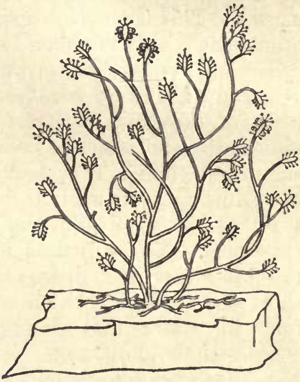

FIG. 14.—*Syncoryne eximia.* After Allman.

margin, leaving only a central hole. This shelf is called the veil, or velum. From the margin of the bell, or umbrella as it is often called, long tentacles project, the number varying in different forms. At the base of the tentacles, or between them, are placed small sense organs, often of much importance in classification. The mouth of the medusoid is placed at the end of the clapper, and opens into a cavity, which communicates with fine canals radiating through the jelly of the bell. All these characters can, in the case of some of the larger swimming-bells, be readily made out, especially in living specimens, and on a calm summer's day no difficulty should be experienced in obtaining living medusoids. Even if a net be not at hand, it is often possible to catch the little creatures from a boat in a small bottle; and there is, perhaps, no better way of studying them than under such conditions, with the sunlight playing on the water and the boat gently rocking beneath the naturalist's feet. Then the delicate pulsating bells take on a new beauty, and every movement displays some fresh charm to delight the eye. It sometimes happens, on an exceptionally calm day, that the surface water simply swarms with medusoids of many shapes and tints, varying in size from tiny creatures, just discernible, as they float along, to those with a diameter of about half an inch. The size should be compared with that of the large jelly-fish, which are not very nearly related to the medusoids.

FIG. 15.—*Sarsia*, or swimming-bell, from a zoophyte colony. After Hincks.

As to the special characters of *Sarsia*, we may notice that in the mature stage the manubrium, or clapper of the bell, is very long and thick, extending downwards considerably below the margin of the umbrella. This character enables one to pick out the tongued *Sarsia*, as it is often called, very easily from other swimming-bells. It, together with the other structural points described, can be clearly made out from the figures. In this tongue, or clapper, the eggs are developed, so that while in *Coryne* the eggs must fall near the parent colony, in *Syncoryne*, by the intervention of the swimming-bell, they are carried away some distance from the parent colony. The swimming-bell seems to exist only that it may perform this function of carrying away the eggs, and in structure it is, as it were, a zooid which has become adapted for a free-swimming life in the open water. Like the zooid it has tentacles, but these are few in number (only four), and relatively very long. They hang down from the margin of the bell, and are abundantly supplied with stinging threads. It should be noticed that though *Sarsia* seems large in comparison with the size of the zooids of *Syncoryne*—it may have a diameter of three-quarters of an inch—yet its bulk is largely due to the contained jelly, which is again largely water.

The last member of the Gymnoblastea which we shall consider is the large and beautiful *Tubularia indivisa*, which again produces sporosacs and not swimming-bells. It is a form in which the stems are sometimes as much as a foot long, and which is especially common on piers and landing stages. It also occurs on rock surfaces and stones on the shore, but usually near low-water mark. If, as sometimes happens, you know that it is growing in abundance on some rocky ledge or pier support not readily accessible with the resources at hand, an indirect method of obtaining specimens may be tried. That is, you may anchor by means of a stone a log of wood in the vicinity of the spot, and you will probably find that in a few weeks the log will become covered with a luxuriant growth of zoophytes, including the desired *Tubularia*. I have seen singularly beautiful specimens obtained in this way. The prudent naturalist will, of course, also not neglect such possible sources of supply as buoys, which are often taken up regularly to be cleaned, old boats left anchored in quiet coves, and wreckage.

One of the special peculiarities of *Tubularia*, by which it is distinguished from any other zoophyte we have described, is the arrangement of the tentacles. These are arranged in two circles, of which the one (*a* in Fig. 16) surrounds the mouth and consists of very short tentacles, while the other (*b* in Fig. 16), whose members are long, is placed at a considerable distance below the mouth. Between the two circles are placed the sporosacs (*c* in Fig. 16), which in *T. indivisa* are borne on branched stalks, and hang down on all sides like little bunches of grapes. The colony is invested with a straw-coloured skeleton, and as the stems are unbranched, each resembles an "oaten pipe." The stems are not ringed, and narrow towards the base, where they are twisted and interlaced. The zooids are bright pink, and project like beautiful flowers from their straw-like tubes. Besides *T. indivisa* with its unbranched tubes there are several other species of *Tubularia*, but these come from deeper water or are less common. The large size of the zoophytes and the beauty of their colouring make *T. indivisa* one of the most beautiful of our Hydrozoa. Each sporosac contains only a single egg, which undergoes the early stages of its development within the sac. The embryo, when set free, has some slight power of independent locomotion, and must also be readily carried about by currents.

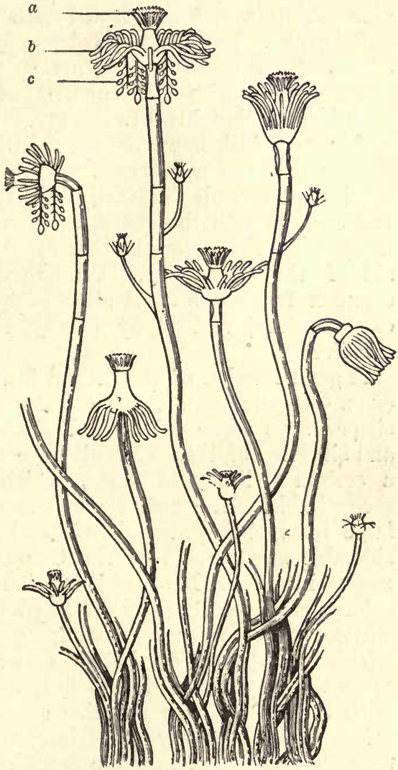

FIG. 16.—Colony of *Tubularia indivisa*, showing the zooids in their tubes. After Allman.

We come next to the true sea-firs (Calyptoblastea), in which the skeleton reaches a much higher degree of development, and which are, above all, remarkable for their delicate tracery. Many of them, as they spread out in the water, show a beauty of form which rivals that of the loveliest of ferns, while others display the coarser fir-like appearance which has given them their common name. The individual zooids are usually much smaller than in the Gymnoblastea, and this fact, together with the greater development of protective substance, gives them less beauty of colour. One rarely finds among them those lovely rose tints which make the colonies of *Clava*, *Coryne*, and *Tubularia* so delightful to the eye. Though the individual zooids are small, however, the colonies often reach a large size, so that the number of individuals is enormous. The species are difficult to identify, and the beginner must often rest content with the genus, or even with the family. In many cases the determination of the species requires the aid of the microscope. On account of the number of common forms, we shall alter slightly our usual method of procedure, and study chiefly the characters of the families.

A great number of the littoral forms are Campanularians (fam. Campanularidæ), and are distinguished by their bell-shaped cups borne on the end of short stalks. The shape and situation of these cups give the members of the family a certain delicacy of form, which makes them readily recognisable. The zooids are remarkable in possessing a large trumpet-shaped proboscis, and generally reach a considerable size. Some of the Campanularians give rise to medusoids, others have sessile sporosacs. In both cases the colony produces specially modified cups (gonothecæ); but while in the one case the cups contain sporosacs within which the eggs ripen, in the other they open early and allow the tiny medusoids to float away, carrying the eggs with them. As each gonotheca may contain many medusoids, and the colony bears innumerable gonothecæ, it is easy to understand how the countless medusoids found at the surface of the sea in autumn originate. While it is easy to recognise a Campanularian, it is often difficult to determine the species, or indeed in some cases even the genus. In most cases the number of teeth on the margin of the cup, and the number of rings on the stems, constitute important points.

Of the many Campanularians on the shore, three species may be briefly described, as they are so common that almost every patch of rocks will furnish examples. If at an exceptionally low tide you make your way right out to the margin of the rocks, where the great oar-weed spreads its long fronds, or if a calm summer day permits the slightly dangerous experiment of a boat among the rocks, you will notice that the oar-weed is often covered by a miniature forest of sea-firs. Especially will you notice one which consists of slender zigzag stems, giving off stalked cups bearing tiny crystalline specks—the expanded zooids. This is *Obelia geniculata*, seen at its best only thus in the Laminarian zone, but in the dead state common enough at all seasons on the torn-off weed of the beach. It gives rise in the summer months to countless myriads of tiny swimming-bells, which are liberated from little cases, or gonothecæ, borne on the stems. If *myriads* seem to you an exaggeration, take a few patches of the sea-fir and make a rough computation even of the gonothecæ produced by a patch of ordinary size. If your patience does not speedily give out, you may acquire some perception of the prodigal profusion of nature on the seashore, and of the intensity of the "struggle for existence" which must go on there, where so many species produce eggs numbered in millions.

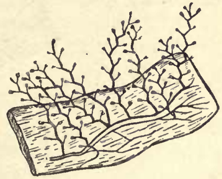

FIG. 17.—*Obelia geniculata* on weed. After Hincks.

Another common Campanularian—*Clytia johnstoni*—is to be found on almost every object within the shore area which offers a foothold—shells, weeds, stones, rock surfaces, are eagerly taken possession of, but the back of a spider-crab is also a dearly prized position. Almost any spider-crab taken at random will show you the simple unbranched stalks of *Clytia*, each ending in a solitary bell, but you should also look for it on rock surfaces, as a good means of training the eye. It is by no means a conspicuous object.

Let us mention one other common Campanularian which is also to be found everywhere between tide-marks. This is *Campanularia flexuosa*, which often grows, intermixed with weed, in patches of great extent, and can be recognised

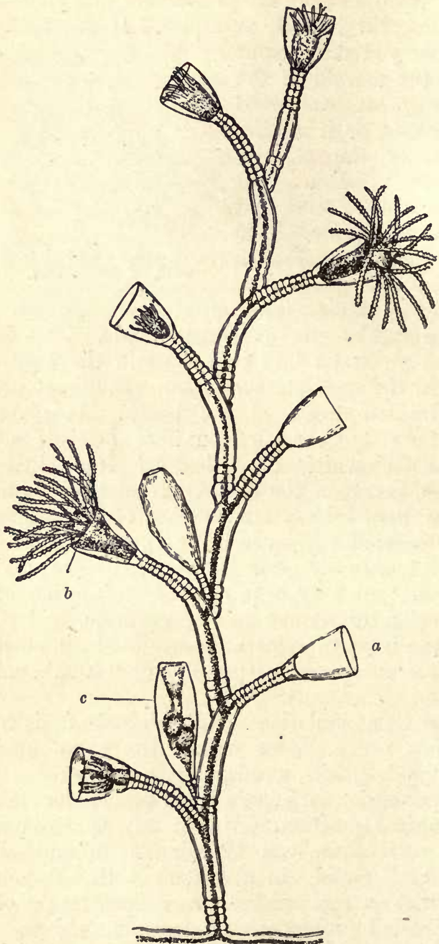

FIG. 18.—Magnified representation of a branch of *Campanularia flexuosa*. *a*. empty cup; *b*, cup with expanded zooid; *c*, gonotheca. Note the ringed "flexuous" stem. After Hincks.

by the large cups and characteristic "flexuous" branching. The figure shows its general characters very clearly. Together with the two preceding species it serves to indicate the characters of the family, and being not inconspicuous, is of some importance in giving rock pools their characteristic appearance. Though the sea-firs must, on account of their horny skeleton, be somewhat indigestible, yet they are eaten by at least the sea-slugs. They also serve as shelters for hosts of the more delicate animals, many of whom pass their lives clinging to their branches. The forests of Campanularians are therefore worth a little study, even if only for this reason.

Though to the

beginner it may seem that the sea-firs are less interesting than some of the more "lively" of the shore animals, we shall rapidly review all the more important families, partly because they afford most interesting examples of progressive evolution, and partly because the study of them constitutes an admirable training in minute accuracy of observation. A wet evening spent over a handful of sea-firs, studied with the aid of the low powers of the microscope or a good lens, will be found of great value to anyone at all interested in species work.

A very insignificant little sea-fir—*Opercularella lacerata*—may serve to indicate the characters of the family Campanulinidæ, which represents the process of transition from the Campanularian condition to that found in other families. This sea-fir has stalked cups, but they are not bell-shaped, but ovate and conical, while the zooids are cylindrical with a short proboscis. A special peculiarity is that the cups can be closed by an elaborate lid, or operculum.

The next stage in the transition from the Campanularian condition is seen in the family Lafoëidæ, where the cups are tubular and almost without a stalk (sessile). The only example we shall consider is *Lafoëa dumosa*, which occurs both on the shore and in deep water. It may reach a height of four inches, and is then erect and irregularly branched, but the specimens found between tide-marks are usually small and have simple creeping stems. The tubular cups are very numerous and spring from all sides of the stem. The whole colony has a yellowish tint.

One other small transitional family must be mentioned, which includes the curious "herring-bone coral," a species often cast up on the beach, and occasionally found between tide-marks. The whole colony is figured on page 319. It is a large form, sometimes reaching a height of ten inches, and is peculiarly stiff and rigid, differing in this respect from the majority of the plant-like sea-firs. The Latin name of this form is *Halecium halecinum*, and it belongs to the family Haleciidæ. The special peculiarity is that the cups are sessile, and are placed in two rows on the stem (see Fig. 19). This recalls the conditions seen in the next family, the Sertularians; but there the cups are let into the stem, while those of *Halecium* are placed on a projecting process, and are tubular or almost campanulate. The stem is much branched, after the fashion called pinnate, and the cups are alternate.

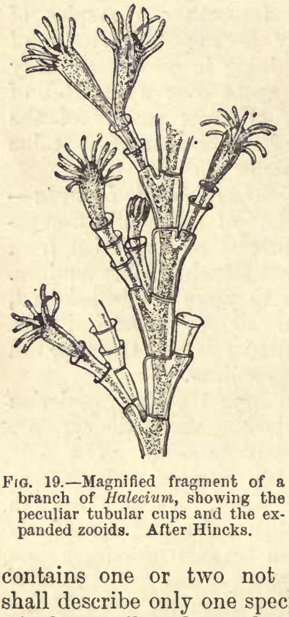

FIG. 19.—Magnified fragment of a branch of *Halecium*, showing the peculiar tubular cups and the expanded zooids. After Hincks.

The next family is that of the Sertularians (Sertularidæ), which includes a large number of forms, usually easy to recognise, and represented both in the living condition on the rocks, and among the dried wreckage of the shore. The cups are entirely sessile and are sunk in the stem, the result being to give the stem and its branches a characteristically stout appearance as compared with the filmy threads of many of the Campanularians. The cups usually occur on both sides of the stem, and the zooids are completely retractile, so that after death they are rarely visible.

The first genus of this family is *Sertularella*, which contains one or two not uncommon littoral forms. We shall describe only one species, chosen because it is not only widely distributed round our own coasts, but also occurs in most seas. This is *S. polyzonias*, a pretty straw-coloured zoophyte, which often reaches a considerable size. Like all the members of its genus, it has its little cups placed alternately, and this, together with their shape, gives a peculiar and characteristic appearance to the whole colony. Each cup has a toothed margin, and can be closed by an operculum made of several pieces. The different species of the genus are distinguished especially by the shape of the cups. In *S. polyzonias* these are urn-shaped, and bulging below with a divergent four-toothed aperture. In fact, they somewhat resemble the calyx of the Figwort. The stems are slender and much, but irregularly, branched.

From the species of *Sertularella* it is usually easy to distinguish at a glance the species of *Sertularia*, which have usually opposite cups, and stems which appear to be made up of a succession of triangular joints, the base of the triangle being directed upwards. By far the commonest species is *S. pumila*, an insignificant little zoophyte, which, with its loosely branching stems, often occurs in great profusion on the shore rocks. It has a special preference for the blades of the larger weeds, and is readily recognised by the regular V-shape of the joints of which the stem is composed. The cups in which the zooids are placed form

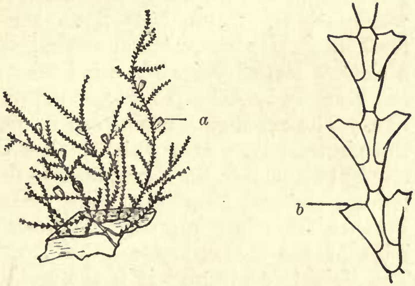

FIG. 20.—*Sertularia pumila*, and a magnified representation of a portion of a branch. *a*, gonotheca; *b*, empty zooid-cup. After Hincks.

the upper part of the diverging arms of the V (see Fig. 20). We may repeat here that to recognise the species of sea-firs requires a little skill and the use of the microscope. The examples which have been briefly described are intended to give the student some notion of the modifications of structure seen in the chief families, and assist in the recognition of at least the family of the common forms. More than this will probably be found difficult for the beginner. Several species of *Sertularia* are fairly common between tide-marks, and others are frequently thrown up on the beach, and are to be found attached to other animals so thrown up. To settle the species of these is often difficult, but it is much to learn that they are Sertularians, and to realise their differences from the other hydroids often so plentiful in the same place.

Before we leave the family two other forms may be briefly mentioned, which differ very much in appearance from other Sertularians. Both do occur occasionally in the Laminarian zone, but are most commonly found among the shore wreckage. There their peculiar shapes have made them both noticeable objects, and have given to the one the name of "sickle-coralline" and to the other that of "bottle-brush." So remarkable is the resemblance of the latter to the object indicated in its common name, that people frequently refuse to regard it as an animal production at all.

First as to the "sickle-coralline" (*Hydrallmania falcata*). It is a large form, reaching a height of a foot or more. Its general appearance may be described in the words of Sir John Dalyell as "a series of feathers implanted in spiral arrangement round a slender stem," but when dried the "feathers," or "plumose branches," become curved or sickle-like. The zooid-cups are placed on one side of the pinnæ only, a fact which makes the whole zoophyte resemble the next family—the Plumularidæ—rather than the other Sertularians. Further, they are placed in clusters on each joint of the stems, and are tubular in shape. The "sickle-coralline" is a zoophyte which is very likely to be mistaken for "seaweed."

FIG. 21.—"Bottle-brush," or *Thuiaria thuia*. After Hincks.

The "bottle-brush" (*Thuiaria thuia*) cannot be honestly described as anything but ugly. It consists of a long naked stem with a small "brush" at the top, and is of a dull brown colour. It may attain a height of twelve inches, but specimens of six to seven inches are more common. The brush varies in size, but not infrequently occupies about one-third of the stem. As the stem grows and branches at the top, the lower branches fall off, so that the brush does not necessarily increase in size with the growth of the colony. In consequence, further, of this method of growth, the naked portion of the stem shows throughout the scars where the old branches have fallen off. The botanist will at once perceive the resemblance in method of growth to a tree-fern, or to many palms. The cups containing the zooids are so sunk into the substance of the branches as to be discernible only with difficulty. They are arranged in two rows.

The last family of the Calyptoblastea is the Plumularidæ, including some of the most delicately beautiful of the zoophytes. Most are beautifully and elaborately branched, so as to produce "plumes" rivalling those of the most delicate ferns (see Fig. 9, p. 29). In all the cups are sunk into the branches, and are placed on one side of the branches only. As they are usually small, one result of this arrangement is to make them very inconspicuous, so that to the unaided eye there is nothing to destroy the *plant*-illusion. The gonothecæ always contain fixed sporosacs. A final peculiar character is that the colony bears, in addition to its zooid-cups, much smaller cups, called nematophores, which contain stinging-cells. These are usually very minute, and require the aid of the microscope before they can be seen. Of the Plumularians we shall describe one example only, the delicate little *Plumularia setacea*, which is quite common on the shore rocks. Its graceful plumes reach a height of over an inch, which is not small for a littoral zoophyte, but their texture is so delicate and fragile that they are not easily seen. Each tiny plume rises independently from the creeping stolon, and is so transparent that, except when the white reproductive capsules are present, it requires a quick eye to discern it. The special peculiarities of the species lie in the minute structure of the pinnæ, or branches. Examined with the microscope these will be found to consist of joints which are alternately long (*d*) and short (*e*), and of which the longer

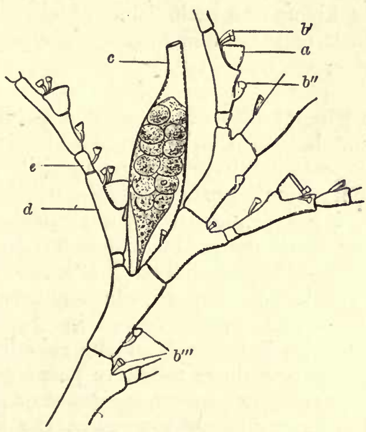

FIG. 22.—Magnified branch of *Plumularia*. The letters are explained in the text.

only bear zooid-cups (*a*), a single one to each. Above each cup are two minute cup-shaped *nematophores* (*b'*), while beneath each is a single one (*b''*). The short joints also bear a single nematophore, but no zooid-cup. Other nematophores occur at the joint of origin of the pinnæ, and on the main stem (*b'''*). The gonothecæ (*c*) arise at the angle between pinnæ and stem, and are remarkable for their long tubular necks.

The Calyptoblastea are so abundant on the shore that even at the risk of wearying the reader, we may briefly review the different families. Sea-firs which bear distinct bells borne on stalks belong to the Campanularians, which have large zooids, and vary much in their branching. Where stalked cups occur which are not bell-shaped, but ovate and conical, the colony must be referred to the Campanulinidæ; but if the cups are numerous, tubular, and without a stalk, then the specimens belong to the Lafoëidæ. In the "herring-bone coral" the cups are similar and also without a stalk, but they are arranged in two rows at the sides of the flattened stem. In the Sertularians the deeply sunk cups, the jointed stems, and the arrangement of the cups make the colonies resemble some firs, or the backbone of a little fish. Finally, the Plumularians are like little feathers, and have their cups placed at one side of the stem only.

From this survey of the littoral Hydrozoa we may gather a general idea of the special peculiarities of these curious and beautiful animals. All the forms we have considered are colonial, living in communities often formed of an enormous number of individuals, which are mutually dependent, and are connected by a ramifying series of canals. In the next group of Cœlentera—the sea-anemones and their allies—this colonial habit is less common in our seas, though even there colonies quite analogous to those of the sea-firs do occur. Again, except in *Hydractinia*, we have found that the individuals of the colonies show little division of labour; we have nutritive persons, or hydroid polypes, and reproductive persons, sporosacs or swimming-bells, but with the exception already made, the hydroid members of any colony are all similar. Now in certain free-living Hydrozoa, which are abundant in warm seas, but very inadequately represented in our own, division of labour is carried to a much greater extent than in *Hydractinia*, and we have floating colonies formed of many different kinds of persons. These constitute the Siphonophora, and are exemplified by such forms as the "Portuguese man-of-war," which is sometimes brought by the Gulf Stream to certain parts of our coast.

Another interesting point about our littoral Hydrozoa is that, as we have already pointed out, they show a considerable range of variation in regard to the power of forming a skeleton. While some, like *Clava*, form scarcely any skeletal substance at all, in others, as for instance the "bottle-brush," the tough coat is much more conspicuous than the living zooids. But whether the coat be well developed or not, it should be noted that it is always horny, and never made of lime. There are a few Hydrozoa which form limy coats (corals), but these do not occur round our coasts.

Lastly, we should note the relation of the zoophyte colonies to the tiny swimming-bells so abundant in our seas in late summer and early autumn. We have seen that these medusoids arise from zoophyte colonies, and are the reproductive persons of those colonies, and we have seen also that while some zoophytes give rise to medusoids, others bear sessile sporosacs. In some cases, as in the Sertularians and Plumularians, this latter condition prevails in a whole family; while in other cases, as in the Campanularians, closely related forms display the two conditions. There seems no doubt that the production of swimming-bells is the more primitive condition, and that this power has been lost by such families as the Plumularians and Sertularians. Probably its loss is associated with the fact that the bells are very liable to be swept away by strong currents to localities quite unsuitable for the hydroid stages, and that distribution by means of minute larvæ is as effective and much less costly than the production of swimming-bells. Nevertheless, we have forms like *Obelia geniculata* and *Campanularia flexuosa*, which seem to live under quite similar conditions, and are both extraordinarily abundant; and of these one bears sporosacs and the other true medusoids. Therefore, though we have much reason to believe that the condition of each is an adaptation to its own particular surroundings, yet we are unable to say how the surroundings differ, or wherein the adaptation consists. Nor can we say that the difference is associated with some other structural peculiarity, for as yet it is not possible to point out any constant difference between those zoophytes which produce medusoids and those producing sporosacs, apart from this prime difference. It is the constant occurrence of phenomena like this which makes shore life so interesting, and its study so helpful to those especially whose scientific training has been largely that of the laboratory.

Though we cannot tell whether a hydroid colony will produce sporosacs or medusoids, apart from the actual experience which shows us what it does produce, yet it is interesting to note that there is a permanent structural distinction between the swimming-bells of the Calyptoblastea and those of the Gymnoblastea, so that we can determine the nature of the colony from which any particular swimming-bell has arisen. We cannot here describe in detail these differences, but may note that in the former case the reproductive elements are produced in the manubrium, or clapper of the bell (cf. *Sarsia*), while in the latter they arise in the course of those radial canals of which mention has been made (p. 47). Both kinds of medusoids are common in our seas, but in most localities those of the species of *Obelia* are perhaps commonest of all. They may be recognised by their peculiarly flattened shape, and the short distinctly four-lipped manubrium. The tentacles are short and numerous, and the four sets of reproductive organs are very distinct. The size varies from about that of a sixpence to that of half a crown, and the creatures resemble transparent plates rather than bells. Another very common swimming-bell, that of *Clytia johnstoni*, is shown in Fig. 90, p. 326. It differs chiefly from that of *Obelia* in having only four tentacles.

We shall conclude this chapter by giving a table which may assist the student in the identification of the common sea-firs.

CŒLENTERA.—Hollow-bodied animals with tentacles and stinging-cells.

Class I.—HYDROZOA.

Sub-class.—HYDROMEDUSÆ.

Order I.—GYMNOBLASTEA. Zoophyte colonies in which the horny investment, if present, does not form cups for the zooids.

Tentacles thread-like.	Tentacles scattered and very numerous.	*Clava.*
	Tentacle in two circles.	*Tubularia.*
	Tentacles in one circle. Zooids not all similar.	*Hydractinia.*
Tentacles capitate, *i.e.* with a terminal knob.	Colonies produce sessile sporosacs.	*Coryne.*
	Colonies produce free medusoids (*Sarsia*).	*Syncoryne.*

CHARACTERS OF SPECIES.

Clava. Two common species, *C. squamata* forming dense clusters on weed, *C. multicornis* with scattered individuals usually on stones.

Coryne. A common species is *C. pusilla*, a small, rather delicate species, with slightly branched stems marked with rings. Tentacles, about thirty, in many circles; zooid long and slender, scarcely tapering below.

Syncoryne. A common and conspicuous species is *S. eximia* which forms bushy tufts on weeds. Stems often several inches in length, smooth save for a few annuli at the base, profusely branched.

Tubularia. In *T. indivisa* the stems are long, unbranched, and smooth. Between the upper and lower circle of tentacles are inserted the grape-like bunches of sporosacs.

Hydractinia. In *H. echinata* the colony forms a pinkish crust on shells inhabited by hermit-crabs. For description see text.

Order II.—CALYPTOBLASTEA. Sea-firs, in which the zooids are placed in horny cups.

CHARACTERS OF FAMILIES.

Fam. Campanularidæ. Cups bell-shaped and stalked.	*Clytia*, *Obelia*, *Campanularia* are not distinguished by any peculiarity of the colonies as a whole, but only by their reproductive persons (see pp. 50–52, 60).
Fam. Campanulinidæ. Cups ovate and conical, stalked.	*Opercularella.* With a distinct operculum (see below).

Fam. Lafoëidæ. Cups tubular and sessile.	*Lafoëa.* Cups very numerous, springing from all sides of the stem.	
Fam. Halecidæ. Cups in two rows, tubular and sessile, borne on projecting processes of stem.	*Halecium.* Stems peculiarly stiff and rigid.	
Fam. Sertularidæ. Cups sessile, sunk in the stem, usually in two rows.	Cups alternate, with toothed margin and an operculum.	*Sertularella.*
	Cups opposite, stem made up of V-shaped joints.	*Sertularia.*
	Cups tubular, on one side of stem only, in clusters.	*Hydrallmania.*
	Cups deeply sunk, branches confined to upper part of stem.	*Thuiaria.*
Fam. Plumularidæ. Cups sessile, on one side of stem only, "nematophores" present.	*Plumularia.* Nematophores distributed along the stem and branches.	

CHARACTERS OF REPRESENTATIVE SPECIES.

Fam. Campanularidæ.

Genus *Obelia.* Contains a number of species, of which the commonest is *Obelia geniculata.* Height about one inch. Stems upright, zigzag, connected at base by creeping stolons, jointed, with stalked cups at the joints. Margins of cups smooth, stalks ringed.

Genus *Clytia.* In *Clytia johnstoni,* which is very common, the stems bear a single terminal cup. Stems ringed at top and bottom, but not in middle ; edge of cup with ten to twelve teeth. Gonothecæ either on stems or on basal stolon.

Genus *Campanularia.* The commonest species is *Campanularia flexuosa.* Stems slender, branched, flexuous, about one inch high. Cups large, tapering below, with long ringed stalks. Gonothecæ large.

Fam. Campanulinidæ.

Genus *Opercularella.* In *O. lacerata* the stem is under one inch in height, erect, slender, ringed throughout ; cups few, on ringed stalks. Cups with segmented margin, the segments being capable of closing over the opening like a lid (operculum). Gonothecæ large.

Fam. Lafoëidæ.

Genus *Lafoëa.* In *L. dumosa* height may reach four inches, stems erect and irregularly branched, or simple and creeping, cups tubular and numerous, arising from all sides of the stem.

Fam. Halecidæ.

Genus *Halecium.* In *H. halecinum* ("herring-bone" coral) height may reach ten inches. Stems rigid, much branched. Cups sessile in two rows on projecting processes, alternate, tubular. Gonothecæ on upper surface of stems, broad and truncate above, with tubular orifice at side.

Fam. Sertularidæ.

Genus *Sertularella.* In *S. polyzonias* the cups are urn-shaped, bulging below, with a divergent four-toothed aperture. Gonothecæ shortly stalked and large. Stems slender, much but irregularly branched.

Genus *Sertularia.* In *S. pumila* the stems are loosely branched, the gonothecæ have a tubular rim.

Genus *Hydrallmania.* In *H. falcata* ("sickle-coralline") the stems are about a foot long, slender, and with spirally-arranged branches. Gonothecæ yellow and tubular.

Genus *Thuiaria.* In *Thuiaria thuia* ("bottle-brush") the stem, which may be one foot in length, bears a cluster of branches at the top. Cups in two rows.

Fam. Plumularidæ.

Genus *Plumularia.* In *P. setacea* the slender, delicate stems are about one inch in height, the plumes arise separately from the creeping stolon. Joints of branches alternately long and short, zooid-cups placed singly on the long joints. For nematophores, see figure. Gonothecæ with long tubular necks.

NOTE ON DISTRIBUTION.

The Sponges and Sea-firs described in this chapter are so common that they may be expected at almost any part of the British area, where the conditions are at all favourable. Their relative abundance at different places varies considerably, however. Thus *Hydractinia echinata*, which is extraordinarily abundant at St. Andrews and in the Firth of Forth, is much less common in the South and West. Again, at places like Torquay and Penzance, not only may many other species be expected on the shore in addition to those mentioned, but a happy chance may furnish the "Portuguese man-of-war" (*Physalia*), to which reference has been made above, and other beautiful free-swimming forms, swept in by ocean currents from the open sea. Though generally speaking the South and West are richer in Hydrozoa than the North and East, yet there are one or two forms which occur in the latter and not in the former localities. The interesting "bottle-brush" (*Thuiaria thuia*), for example, is said to be rare off the coasts of Cornwall and Devon.

CHAPTER IV.

SEA-ANEMONES AND THEIR ALLIES.

Differences between sea-anemones and zoophytes—Four common sea-anemones, their habits and characters—Variation in sea-anemones —"Dead men's fingers" in life and after death—The sea-pen—The Jelly-fishes—Life-history of Aurelia—Relation to Lucenaria—The Ctenophora, or "iridescent fire-globes."

SO far we have been concerned with the simplest of the Cœlentera, where any complexity which may occur is the result of the combination of individuals, and not of the characters of the individuals themselves. Furthermore, as we have repeatedly emphasised, the individuals are always small, often very small, and alternation of generations is always clearly indicated, though there is a tendency for it to become suppressed. In all the cases we discussed where the alternation disappears, it is the active medusoid stage which is lost. The second class of Cœlentera, which we are to consider in this chapter, is in many respects very sharply contrasted with the Hydrozoa. The individuals are often large; colonies, in our seas at least, are relatively less frequent; the structure of the individual is more complex than in the Hydrozoa; there is either no trace of alternation of generations, or, where it occurs, the active jelly-fish stage tends to be accentuated at the expense of the stationary stage. This class is often called the Scyphozoa, and is held to include the sea-anemones and their allies (Anthozoa), and the big jelly-fish. By some authorities, however, the jelly-fish are placed in a separate class. As we shall be very little concerned with the jelly-fish we need not discuss the question of their position, but may merely emphasise their distinctness from the swimming-bells of the Hydrozoa, which are much smaller and less complex.

Of the Scyphozoa the most interesting to most people are undoubtedly the sea-anemones, with which we may conveniently begin. The anemones are almost always beautiful and brightly coloured, they live well in captivity, they are common and conspicuous; facts which easily explain their popularity, even with persons who shrink from sea animals in general as always slimy and possibly noxious. Their popularity has been assisted by the fact that in Gosse's *British Sea-anemones and Corals* we have a readily accessible book which, from its wealth of illustration and clear descriptions, enables the veriest neophyte to name his finds. Unfortunately, the anemone-lover whose habitation chances to be on the East Coast is not likely to find a great variety of forms. While the rocky, wave-swept shores of Devon and Cornwall are often veritable gardens of sea-flowers, our sandy beaches produce a few species only, and these the commonest and hardiest kinds. On the shore rocks of the East Coast we cannot hope to find more than four species, and among these we miss the beautiful *Anthea cereus*, which at so many spots on the South and West flourishes in gorgeous beauty between tide-marks.

We may take first the most abundant and obvious of all our native anemones, the smooth anemone (*Actinia mesembryanthemum*, Fig. 23), which can live everywhere and anywhere, asking only a firm basis of attachment, and a situation between tide-marks. If you find a clear pool containing a specimen in full expansion you may proceed to study the general characters of sea-anemones. The general "polype" shape is of course obvious, the body consisting of an attached *base*, an upright *column*, and a *disc* bearing a central *mouth* surrounded by numerous *tentacles*. Touch the tentacles with your finger, and you will find that they have a peculiar sticky feeling, due to

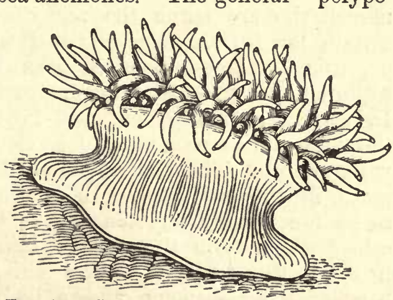

FIG. 23.—Common smooth anemone (*Actinia mesembryanthemum*). Note the beads at the base of the tentacles.

the ejection of their numerous stinging-cells, which are too weak to pierce the skin. When molested the anemone does not shrink down in the way in which the hydroid zoophytes do, but contracts a circular muscle at the top of the column, and pulls the tentacles inwards at the same time. The result may be compared to the closing of a bag by drawing a string run in its margin. The mouth is a longitudinal slit, whose walls are much grooved. Of the grooves two are more distinct than the others, and constitute the "siphonoglyphes," which are structures of considerable interest to the student of form. It is not easy to get a practical notion of the internal anatomy of a sea-anemone without subjecting it to special treatment; but sometimes some of the more transparent species can be studied in the living condition by holding expanded specimens in a glass jar up to the light. The more important points may be briefly summarised as follows. The mouth opens into a short gullet, which itself opens into the general cavity; this gullet can be clearly seen when, as often happens, captive anemones partially turn themselves inside out, and is produced by an infolding of the body-wall. The gullet does not hang freely in the general cavity, for a number of partitions or mesenteries run from it to the body-wall, so that a cross-section of the upper part of a sea-anemone would show a central chamber surrounded by radial chambers. These radial chambers are traversed by other narrow mesenteries which project from the body-wall, but do not extend inwards so far as the gullet. On the mesenteries are borne the reproductive organs, and also certain tangled threads, supposed to be of importance in digestion. These are often seen when an anemone is ruptured in the attempt to remove it from a rock surface. In certain anemones, but not in the smooth anemone, the mesenteries also bear long, slender threads, crowded with stinging-cells, and capable of being shot out by pores in the body-wall. In *Actinia* these *acontia* seem to be functionally replaced by the "batteries of stinging-cells," which form the row of blue beads visible at the base of the tentacles. The chief points of contrast between a sea-anemone and a hydroid polype are: the presence in the former of a distinct gullet, of mesenteries or partitions, and of "digestive filaments," the tangled threads mentioned above.

As to the special characters of *Actinia mesembryanthemum*, note the very smooth column, which is always short relative to its diameter; the rather short tentacles, which number about 200, and usually in the expanded condition curl over the margin of the disc. The mouth is elevated on a blunt cone, and the row of blue beads is very characteristic. There is always a narrow blue edging round the base, but in the other parts of the body the colours are very variable. The three common tints are dark red, olive-brown, and green, but in many cases the column is streaked and spotted with lighter colours. This anemone lives well in captivity, and then often gives rise to numbers of tiny semi-transparent young, which make the daintiest of pets. As sea-anemones are so familiar, it is, however, probably unnecessary to expatiate on the habits at length. Gosse names and describes a number of varieties of the smooth anemone, but perhaps the most important point for us is to emphasise the great adaptability of sea-anemones in general. They are, of course, of relatively low organisation, and seem capable of varying in harmony with their environment to a very marked extent. The variability is often displayed by modification in colour, which we have, perhaps, no reason to regard as adaptive, but it is also often shown in other characters. This is well seen in the next sea-anemone, *Tealia crassicornis,* the thick-horned anemone, which in abundance comes only next to *Actinia.* It inhabits both deep and shallow water, and between tide-marks sometimes lives in rock pools which never become dry, and at other times under overhanging rocks among gravel and sand. In these different situations it exhibits noticeable structural differences, while of colour differences there is an almost endless variety.

What may be called typical specimens are to be found under sheltering stones where the sun does not reach. At low tide the anemones form an almost indistinguishable mass of stones and shell fragments, but are yet sufficiently alive to squirt vigorous jets of water at an intruding naturalist, at the same time cowering down yet more closely among the débris. If an attempt be made to remove the specimens, it will be found that they are attached, not to one smooth surface, but to a number of objects, in a fashion that makes them difficult to extricate without injury. Further observation in a neighbouring pool will probably disclose some other fully expanded specimens in which the characters can be studied. The anemone is characterised by the size of the base as compared to that of the column; it is a low, flattened animal, with a diameter often of several inches. The tentacles are short, very thick, and not numerous; they have none of the snaky appearance usually

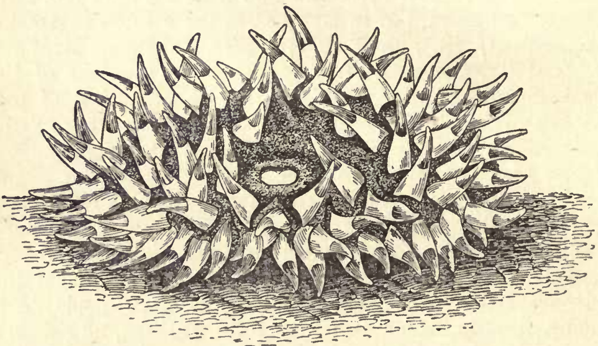

FIG. 24.—*Tealia crassicornis*, the thick-horned anemone. Note the central mouth, and the stout, banded tentacles. After Tugwell.

associated with anemones' tentacles. The surface of the column is covered by distinct warts or papillæ, to which shells and stones are attached. The colours vary, but reds and greens are common, while the tentacles are banded with white, and have very distinct reddish bands round their bases, which extend over the disc towards the mouth.

Though the majority of the thick-horned anemones found between tide-marks are of this type, yet in those narrow rock-clefts which are swept clean by the tidal currents but never completely emptied, another variety occurs. At North Berwick, for example, the shore rocks are hollowed out into many fissures and crevices, and it frequently happens that a cleft, which from above seems narrow enough, widens out below into an extensive deeply shaded pool. If by any means you can wedge yourself down the cleft, and obtain a foothold in the cavern beneath, you may see dozens of specimens of *Tealia crassicornis* in full expansion, and in almost every variety of tint. They attach themselves to the perpendicular rock-walls, and, apparently as a result of this mode of attachment, show a much more typical "anemone-shape" than their flattened brethren of the tidal pools. That is, the column reaches a height equalling the diameter of the disc, and is truly columnar; whereas in the other form it is short or squat. Again, these deep pools contain no shell sand or gravel, and the anemones are in consequence destitute of covering, while the functionless warts have become small and inconspicuous. The colouring is brilliant, and it not infrequently happens that the tentacles are uniformly coloured throughout, or have merely a paler spot near the tip. In the commoner form they are distinctly banded, which, from the artistic point of view, is a much less effective scheme of coloration. A colony of such anemones, all of large size and all in full expansion, forms one of the most beautiful of the many beautiful sights of the shore, and I know few more fascinating occupations than that of successfully forcing one's self into these caverns, and while maintaining a somewhat uncertain foothold on the slippery sides, studying every detail of colour and form. The roar of the breakers at the mouth of the cleft, and the rush of water, now in and now out, adds the spice of danger to the occupation which is essential to fill up the tale of pleasurable sensations. These anemones, unlike those in shallow pools, are easily detached without injury, but they rarely live well in captivity; they doubtless miss there the abundantly oxygenated water of their natural habitat. If the t de permit it is easy in that natural habitat to make observations on the diet. In spite of their frequently fragile appearance the anemones in general are far from having fairy appetites, and *Tealia* is especially voracious. It seems to have a special preference for crabs, and may often be seen disgorging the remnants of its victims. In a quiet pool, indeed, I have seen a regular heap of dejecta beneath the anemone—a veritable kitchen midden on a small scale. It is interesting to note that the colour of the shell of the shore crab is changed by the digestive process from greenish to red—a change which it is easy to imitate in the laboratory by immersing a fresh shell in dilute acid. Also, the hard shell has been rendered brittle and is easily pulverised. From these observations we might deduce the conclusion—which has, indeed, been reached by experiment —that the anemone secretes an acid digestive fluid.

Next in order of abundance on the East Coast comes the cave-dwelling anemone (*Sagartia troglodytes*), a form which in spite of its abundance is much more difficult to find than either of those already mentioned. If you are idly gazing into a shallow rock pool floored with variegated sand or fine gravel, you may sometimes find that as you gaze certain star-like patches differentiate themselves from the background by a regularity of shape, not to be ascribed to current action. If you touch these spots in order to investigate the matter, the star disappears, leaving an ill-defined hollow. Study this phenomenon still more closely by scraping the sand away with your fingers, and you will find a small sea-anemone, attached to the rock surface which floors the pool, and protruding its crown of tentacles through the sand. The attachment is relatively slight, and the anemone can be readily removed and placed in a clean pool or a collecting jar. It is very contractile, and by the time the process is completed will probably be reduced to the condition of a brownish button, partially invested in its own white stinging-threads (acontia), which are shot out in abundance as soon as it is touched. It rapidly recovers, however, and will probably soon unfold its tentacles, and display the variegated marking which gives them so deceptive

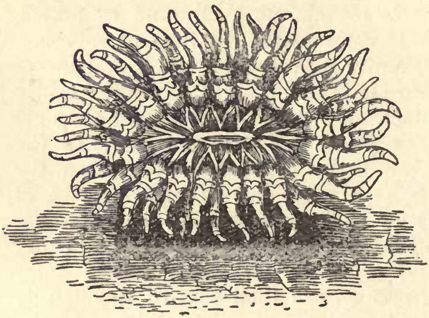

FIG. 25.—The cave-dwelling anemone, *Sagartia troglodytes*. Note the beautifully marked tentacles, and especially the B-mark at their base.

a resemblance to sand. The column is long, often very long, and cylindrical, and in its upper two-thirds is covered by distinct suckers, to which fragments of stone and shell are often attached. On the other hand, in a sandy pool it is not uncommon to find specimens which, instead of being covered with isolated fragments of gravel, have a complete investment made of fine sand glued together by mucus. This can be peeled off, and leaves the smooth column below. The cave-dweller does not always live in sandy pools, but, as the name indicates, is often found in rock crevices. There the colours are brighter, the prevailing tint being greenish brown or grey-violet. They are also often abundant in the beds of young mussels which sometimes cover the flat surfaces of rocks. The young mussels are, as it were, embedded in a thick layer of silt, which intervenes between them and the rock surface. The anemones are attached to the rock like the mussels, and protrude their starry crowns through the layer of silt, while the shells of the mussels make a firm wall around them. If you look at such a young mussel-bed from a distance of a few feet, you will notice that the uniformity is interrupted by numerous rounded spaces, in which the silt and sand show out in contrast to the dark shells of the surrounding mussels. A close examination will show you that each gap is occupied by a flourishing *Sagartia troglodytes.* The sight is an interesting one, and suggests many problems. What does the anemone gain from the association? Is it a true case of an "animal association," or is it merely a chance that the same environment should suit both? Does the anemone obtain any of those benefits somewhat vaguely summed up in the word protection, or is it that it shares the food of the mussels? These are only a few of the questions one would like answered.

The cave-dweller lives so well in confinement, and its markings so well repay study, that a few should be taken home for the purpose. In one habit it differs remarkably from the two preceding anemones. They will rarely expand freely unless the base is firmly fixed, and as every aquarium keeper knows, they will never thrive unless they can be persuaded to attach themselves almost at once. The cave-dweller, on the other hand, rarely completely retracts its tentacles, and will often expand fully while lying loose in a jar. It never fixes itself very firmly, and the "cave-dwelling" habit is no doubt associated with the fact that it seems unable to cling tightly enough to resist wave-action, and must therefore seek protected crevices.

As to coloration, though the actual tints of column, disc, and tentacles show much variation, yet there is considerable constancy in the markings, which constitute important specific characters. The column is marked with light stripes most conspicuous towards the base, the disc is beautifully marked with radiating bands, each band being patterned in dark and light tints, and at the base of the tentacles there is a black mark of the shape of a B, the curves being directed towards the mouth. This B-mark is eminently characteristic of *Sagartia troglodytes.* Finally, the tentacles themselves are banded in dark or light tints, and are of much importance in producing the resemblance to sand so characteristic of the expanded anemone.

There are a number of other species of *Sagartia*, mostly showing some indication of the elaborate patterns of *S. troglodytes*, but these do not occur, between tide-marks at least, on the East Coast, and naturalists living on the West may be referred direct to Gosse's book.

The last of our East Coast species is *Actinoloba dianthus*, the plumose anemone, a form which is often said to be an inhabitant of deep water, but which in sheltered places is not uncommon between tide-marks. On the Clyde it has a special preference for the supports of piers, and there occurs in the most gorgeous profusion, clustering thickly about the whole length of the uprights; the smaller specimens between tide-marks, the larger further down, so that their pale tints gleam faintly through the green depths of water, and the outlines of their translucent bodies are hardly discernible in the dim light. In such situations they reach a great size, having a column some six inches long, with a disc of several inches in diameter. But it is only under exceptional circumstances that such specimens can be seen close inshore, certainly not as a rule in the shallow waters which fringe the beach on the East Coast. There one cannot look for specimens of more than an inch or so in height, and as already mentioned, these usually occur in sheltered places only. Often they are found under overhanging rocks or in deep and dark rock crevices, but on the Firth of Forth, on the other hand, I have found numerous specimens growing fully exposed to view on loose stones on the shore. In this, as in many other cases, we require more evidence before we can determine what it is that renders a locality suited to the

FIG. 26.—The plumose anemone (*Actinoloba dianthus*). Note the "parapet," or ridge, beneath the frilled disc. After Tugwell.

needs of the species; it may be a protection against violent wave-action which is necessary, or the abundance of some particular kind of food, or a constant supply of pure water, or some other unknown environmental condition. Certain it is that this is a local anemone, abundant where it occurs, but often absent from apparently suitable spots. It is also very variable in colour, being sometimes white, sometimes yellow, sometimes flesh-coloured. The fact that all three colour varieties may occur in the same situation seems against the supposition that the colour variations are "adaptive," or directly determined by the environment.

As to the general characters of this anemone, notice the smooth cylindrical column, with no trace of suckers, but with minute pores, from which acontia may be emitted. The upper margin of the column is thickened, and forms a "parapet," which is separated from the frilled disc by a groove or fosse. It is this frilled or puckered disc which is so distinctive a character of the anemone. It is very thin, and bears very numerous small tentacles, banded with white, the whole appearing like the "foliated crown of a palm tree." The mouth is grooved, usually has its margins highly coloured, and has one, two, or three siphonoglyphes (see p. 66)—a very interesting range of variation, which also affects the mesenteries internally, and which you should not fail to notice.

The plumose anemone lives well in captivity, and is remarkably active for a sea-anemone, continually changing its position, but generally keeping very close to the surface of the water, where the oxygen must be most abundant. Often in the course of its movements it leaves a fragment of the wide base behind it, and this fragment may grow into a new anemone. Both in captivity and in natural conditions it has a curious habit of distending a part of the body with water while the disc and tentacles are retracted, and then drops in a limp and flaccid way from its point of attachment —a translucent shapeless mass. In the young specimens the tentacles are not so numerous, and the disc is not distinctly frilled, but even at this stage it is hardly possible to confuse it with any other anemone.

Related to the sea-anemones are the Alcyonarians, which are represented on the shore by *Alcyonium digitatum*, or "dead men's fingers." It is a colonial form, consisting of a number of small polypes embedded in a fleshy mass. After death the fleshy substance is much more conspicuous than the polypes, and in the condition in which it is tossed on shore after storms is not a pleasing object, for there is no beauty of form, and the colour is too "fleshy" to be prepossessing. In the living condition, on the other hand, with its glassy polypes fully expanded in a quiet pool, it is a singularly beautiful creature, and one very well worth study.

Though perhaps not a strictly littoral form, in sheltered situations large colonies may often be found between tide-marks, usually in company with *Actinoloba dianthus.* Probably in both cases shelter from violent wave-action is indispensable, and it is only where this is attainable that life in the littoral zone becomes possible for either. Small colonies with a diameter of perhaps $\frac{1}{4}$ inch to $\frac{1}{2}$ inch are often common in rock pools, but the full-grown colonies form bulky lobed masses, several inches in height and diameter. The fleshy substance (cœnosarc) is yellow or pinkish, but the polypes themselves are clear and colourless. They each bear eight tentacles, while sea-anemones have their tentacles in multiples of six. Further, each tentacle is *pinnate*, or fringed with small processes arranged like the barbs of a feather, the result being to produce a beautiful star-like crown when the tentacles are spread out in the water. The internal anatomy generally resembles that of sea-anemones, and some of its details may be made out through the transparent body-wall. Each polype is placed in a small cavity of the pulp or cœnosarc, into which it may be retracted. The cœnosarc contains a series of canals, which place the polypes in communication with one another, and is strengthened by limy spicules scattered through its substance.

Related to *Alcyonium* is the very beautiful sea-pen (*Pennatula phosphorea*), which occurs freely in deep water, and may sometimes be obtained from the fishing-boats. It is in the form of a fleshy plume of red colour, the upper region bearing numerous polypes like those of *Alcyonium.* It has a central rod of lime in its lower region, and so leads up to the red coral of commerce, which is in reality the supporting axis of a fleshy cœnosarc bearing numerous polypes like those of *Alcyonium.* It thus differs markedly from the majority of the "corals" which are made by the aggregation of many limy cups containing polypes; that is, are built on the same plan as the horny skeleton of a Campanularian. In the red coral there are no cups, for the polypes are placed in a fleshy cœnosarc, as in *Alcyonium*, this being removed during the process of preparation of the coral. It may perhaps be well at this point to spare a few words to repeat that "corals" are the hard parts of Cœlentera, and therefore have nothing whatever to do with Insects, so that that artless little metaphor about the devotion to duty exhibited by the "coral insect," which has rooted itself so deeply in the mind of the popular orator, is sheer nonsense—a not uncommon characteristic of oratorical "scientific analogies."

We have already mentioned the fact that the big "jelly-fish," as distinct from the delicate swimming-bells, appear to be related to the sea-anemones and Alcyonarians rather than to the Hydrozoa. Of these jelly-fish only some three or four are common round our coasts, but these often occur in such countless numbers that they are more or less familiar to everyone. We shall only describe one of these in detail, choosing it because certain stages in its life-history are to be found on the shore rocks. This is *Aurelia aurita*, easily recognised by four horseshoe-shaped purple bands seen on its dorsal surface, and recommended by the fact that it can be handled without danger of being stung, so far, at least, as my experience goes. Let us begin with the larva, which is certainly minute and harmless enough. It is a little creature called a hydra-tuba, is pure white, and is to be found *attached* to rocks by one end of its body, while the other is furnished with a mouth surrounded by waving tentacles. It is, you may say, merely a polype of a type with which you are now quite familiar. This is indeed the case, but it has been shown that, small and simple as it appears, the hydra-tuba in certain points suggests connection with the sea-anemones and not with the Hydrozoa. It is usually not more than one-eighth of an inch in height, and is to be found far out on the rocks. In late summer it undergoes certain changes presently to be described, but, oddly enough, these changes may sometimes be arrested for an apparently indefinite period. I have seen captive specimens which the owner assured me had been kept for several years without showing any signs of change. Under natural conditions, however, the little hydra-tuba elongates and becomes marked by a series of transverse lines, so that it appears like a pile of saucers. A little later the top "saucer" floats off, turns over, and becomes a little jelly-fish which grows rapidly and becomes an *Aurelia.* The same thing occurs with the lower "saucers" of the pile, so that the tiny hydra-tuba gives rise to a number of large jelly-fish. There seems almost no limit to the size a jelly-fish may reach, but specimens of *Aurelia aurita* round our coasts commonly vary from six inches to a foot or more in diameter. If this be compared with the minute size of the hydra-tuba, and the relative sizes of the sea-firs and their swimming-bells be recalled, it will be clear what is meant by the statement on page 64 that in the alternations of generations seen in the jelly-fish, the free-swimming stage is accentuated at the expense of the sedentary stage.

To get a general idea of the structure of a jelly-fish, some specimens of *Aurelia aurita* should be obtained. They are usually very abundant in August, and care should be taken to obtain one or two *living* specimens not too large to be readily observed. The living animal is much more attractive than the flattened, half-melted creature so often left on the beach by the ebbing tide. In it the umbrella is sharply curved, not flat as in dead or relaxed specimens, and its slightly inturned margin is furnished with numerous slender tentacles of perhaps a couple of inches in length; after death these are always much contracted and become inconspicuous. The manubrium, or clapper of the bell, is divided into four somewhat short arms, having the mouth opening in the centre. You should not fail to notice that in some others of our jelly-fish (*Cyanea*, *Chrysaora*) the tentacles are very long, and so are also the frilled and puckered arms of the manubrium. As to the other characters of *Aurelia*, the four horseshoe-shaped reproductive organs are very obvious, and by turning the animal over you see that beneath each of these is a little pit, opening to the exterior by quite a distinct orifice. These are often called "respiratory" or genital pits, but are believed by some authorities to be remnants of larval structures. There is no "veil" like that of the swimming-bells, but the jelly is traversed as in them by a series of radial canals, in this case rendered very obvious by their violet tint. At the margin of the bell there are eight sense-organs, or "tentaculocysts," which are easily made out.

Related to *Aurelia* there are, as already mentioned, some other jelly-fish, often of large size, and sometimes with very distinct stinging power. The very large forms are more likely to be found on the West than on the East Coast, and in any case are somewhat beyond our scope. There is a small, delicate creature, however, to be found on the rocks which is related to the jelly-fish, though it differs from them markedly in appearance. This is *Lucenaria*, or as it is now called, *Haliclystus octoradiatus.* It is, perhaps, rather umbrella-shaped than bell-shaped, but there is nothing to represent the stick of the umbrella — that is, no manubrium — and the region of the body opposite the mouth is prolonged into a short stalk which is attached to weed in the pools. The free margin of the umbrella bears eight groups of short tentacles, and the mouth has the usual central position. It is an animal which is difficult to find, though perhaps it is not very uncommon, and reaches a size of one inch or so. The difficulty is largely due to its delicacy and transparency, and to the fact that in colour it usually resembles the weed to which it is attached. It shows no trace of alternation of generations, and is interesting on account of a certain general resemblance to a hydra-tuba, so that one might suppose that it was a larval jelly-fish which had forgotten to grow up, and had become adapted for a sedentary life. It is not a perfectly stationary form, but possesses some power of moving about, and by attaching itself, first by the stalk and then by little marginal tubercles which alternate with the tentacles, can progress like a "looping caterpillar." It is a charming little creature, but, so far as my experience goes, not easy to keep in confinement. The colour is very variable, being brown, green, or claret-coloured, according to the colour of the surrounding weed. The accompanying figure should make the structure obvious.

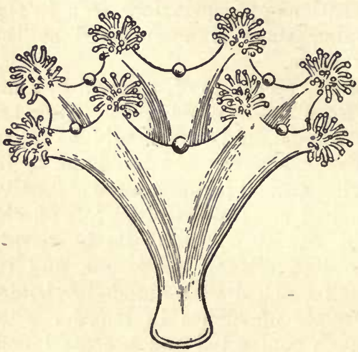

FIG. 27.—*Haliclystus octoradiatus.*

The third and last class of the Cœlentera includes a few beautiful free-living forms to be found floating at the surface of the sea. They may occasionally occur in the rock pools, but are more likely to be found in the open water, where they may be seen as little iridescent bells floating past the boat, in company with the tiny swimming-bells and the giant jelly-fish. These iridescent globes of jelly are members of the class CTENOPHORA, and differ markedly both from the true jelly-fish and from the swimming-bells. Two genera are not uncommon, *Beroë* and *Pleurobrachia* (see Fig. 93), sometimes called "iridescent fire-globes," or "sea-gooseberries." In the former the body is oval in shape with a wide mouth occupying the whole of the under surface, in the latter it is somewhat pear-shaped with a small mouth. When removed from the water both are colourless and delicately transparent, but when seen in active movement in the water both gleam with rainbow tints. This is due to the fact that the long axis of the body, from pole to pole, is traversed by eight bands of motile plates (four of these are shown in the figure), which in life are in constant movement, and propel the animal through the water, while by breaking up the light they also produce the changing play of colour. The structure of the body in both *Beroë* and *Pleurobrachia* is a little complicated, so we need only notice further that the latter, but not the former, has two very long delicate tentacles which can be instantly retracted, or allowed to stream out like a long train behind the body (see Fig. 93). Both are most delicately beautiful animals in life, and should be looked for every summer, if only for the sake of their play of colours and graceful movements. As in the jelly-fish, most of the charm is lost after death.

Perhaps it may be thought that in this and the preceding chapter we have eulogised *ad nauseam* the delicate beauty of a group of animals known to most people chiefly as "nasty stinging jelly-fish," but it is difficult to tear one's self away from a group whose members are adapted for so many different kinds of surroundings, and yet are essentially so simple and so uniform in structure. Their fascination, too, is enhanced by association, for many of them are "fair-weather animals," and all must be studied in the open air for their beauty to be fully appreciated. To anyone who knows them well, the very thought of *Beroë*, or medusoid, brings back a vivid recollection of summer days spent idly drifting over sunlit seas, when every rippling wave displays new shapes of beauty, new gleams of rainbow colour. The zoophytes similarly recall hours spent at the side of clear rock pools, yielding every moment new charms to patient search, new combinations of colour to the educated eye. Even those to whom animals as a rule appeal but little may be recommended to examine these sea-flowers, which are to be found in every pool, and may be studied there in all their beauty, without apparatus and without interference. They are also especially suited to those who shrink from comparative anatomy, as a rule, because it involves the death of the object studied, for most of the Cœlentera can only be properly investigated in the living condition, and will yield many of their secrets to the unaided eye of a patient observer.

We have added to this chapter a table which may not only assist in the naming of specimens, but also in enabling the student to appreciate the number of different kinds of animals included in the group Cœlentera.

CŒLENTERA—*continued from p.* 61.

Class II.—Scyphozoa.

Sub-class I.—Anthozoa. Sedentary polypoid forms, simple or colonial.

Order I.—Zoantharia. Tentacles simple, in multiples of six, sea-anemones.

Column with suckers	Tentacles slender. Acontia present.	*Sagartia.*
	Tentacles very thick. No acontia.	*Tealia.*
Column quite smooth	Tentacles very small and numerous, disc plumose. Acontia present.	*Actinoloba.*
	Tentacles not very small, with blue beads at their base. No acontia.	*Actinia.*

Order II.—Alcyonaria Tentacles feathered, in multiples of eight, all colonial.

Cœnosarc lobed, with scattered spicules	*Alcyonium.*
Cœnosarc pen-shaped, with a central axis	*Pennatula.*

Sub-class II.—SCYPHOMEDUSÆ. Jelly-fish with subgenital pits and no velum or veil.

Order I.—DISCOMEDUSÆ. Active forms with complicated life-history. Four horseshoe-shaped genital organs . . . *Aurelia.*

Order II.—LUCENARIÆ. Sessile forms . . *Haliclystus.*

Class III.—CTENOPHORA. Free living forms with eight rows of plates.

Two tentacles and small mouth . . . *Pleurobrachia.*
No tentacles and wide mouth . . . *Beroë.*

SUMMARY CLASSIFICATION OF CŒLENTERA, OR SEA-NETTLES.

Class I.—HYDROZOA (Chap. II.).

A. Order Hydromedusæ . { (*a*) Gymnoblastea, polypes without protective sheath, *e.g. Clava* and other common zoophytes. (*b*) Calyptoblastea, polypes placed in cups, *e.g. Obelia* and other common sea-firs. }

B. Order Siphonophora . { Free-swimming colonies, like "Portuguese man-of-war." }

Class II.—SCYPHOZOA (Chap. III.).

A. Sub-class ANTHOZOA.

1. Order Zoantharia—sea-anemones and corals.
2. Order Alcyonaria—"dead men's fingers," sea-pens, etc.

B. Sub-class SCYPHOMEDUSÆ.

Various orders, including the large jelly-fish and *Haliclystus.*

Class III.—CTENOPHORA. Free-swimming forms like the "sea-gooseberries" (*Beroë*), etc.

NOTE ON DISTRIBUTION.

The sea-anemones described in this chapter have been those of the East Coast, which is poorer in species than any other part of our area. It is not possible to name all the common anemones of the South and West, but a few notes may be given. In most places on the West the beautiful *Anthea cereus*, an anemone with smooth column and non-retractile tentacles which occurs in a brown and a green variety, is common. It is especially common on the coasts of Devon; north of Devonshire, so far as my experience goes, the brown variety is commoner than the green, which is much the handsomer. Again, while at Alnmouth, St. Andrews, and on the shores of the Firth of Forth, *Sagartia troglodytes* is excessively common, it is probably less common on the South and West—is certainly rendered less conspicuous by the occurrence of many other somewhat similar species. At Millport, for instance, *Sagartia miniata*, which has the outermost row of tentacles with a scarlet core, is one of the commonest anemones of the pools. Another species, *Sagartia bellis*, or the daisy anemone, is very common on the coasts of Devon and Cornwall.

CHAPTER V.

THE BRISTLE-WORMS.

Different kinds of worms—Nematodes—Polychætes—External appearance of Nereis—Structure of the fisherman's lob-worm—Habits of worms—Common shore worms—The scale-worms, or Polynoids—The leaf-worms, or Phyllodocids.

THE group of "worms" is an exceedingly large one, and includes a great number of forms not closely related to one another. Many of these are, however, small or rare, and need not trouble us here, so that we shall consider in detail two sets only—the ribbon-worms (Nemertea) and the bristle-worms (Chætopoda). Two other sets—the round-worms (Nematoda) and the sea-mats (Polyzoa) are almost certain to be also encountered on the shore, and should be briefly referred to. The Polyzoa will be discussed after we have studied some more representative forms, but the Nematodes may be dismissed in a few words.

In turning over stones on the shore, in search of nobler prey, one not infrequently comes across little white or almost transparent worms, which move with an active wriggling motion, and are rounded in cross section. They are especially abundant in pools containing decaying organic matter or odoriferous mud. These are round worms, or Nematodes, harmless enough in this case, but nearly related to some of the most dangerous parasites of man. Almost always of this dead white tint, there is something in their very appearance which suggests their degraded and repulsive mode of life. In spite, therefore, of the fact that they exhibit many points of zoological interest, we may allow our instincts to guide us in passing them by, especially as their small size unfits them for our purposes. As these purposes are the acquisition of a practical knowledge of the structure of worms, we shall begin with the bristle-worms, or Chætopoda. They are more highly differentiated than the ribbon-worms, are often of considerable size, and are easy to examine and dissect.

The Chætopoda (or "bristle-feet") include two main sets of worms—the marine forms (the Polychætes), worms usually with *many bristles*, arranged on lateral outgrowths of the body (the parapodia or feet), and the Oligochætes, worms like the common earthworm, living in earth or in fresh water, and having only *few bristles.* It is the marine worms only with which we are concerned here.

The first step is, of course, to find the worms, but this is considerably easier than in the case of the historic hare. There is no shore so barren and desolate that it does not at some point or other show traces of the bristle-worms. On the mud-flats at the mouths of the rivers, on the smooth sandy shore at the edges of the rocks, or in the sandy bays in the middle of the rocks, one finds in abundance the "castings" of the common lob-worm. The dark seaweed thrown up by the breakers nearly always bears upon its fronds the little coiled dead-white tubes formed by the tiny *Spirorbis.* Among the débris which accumulates at tide-mark, a careful scrutiny will almost always reveal the neatly made tubes of *Terebella* decorated with particles of shell and stone, and encircled at the tip by a fringe of stiff sandy threads. The shore rocks are often in places covered with masses of the sandy tubes of *Sabellaria*, which look themselves like an outcrop of porous rock. We might, indeed, continue the list almost indefinitely, but let us first choose a typical form for closer study.

In turning over stones on the rocks between tide-marks, especially in slightly muddy pools, you are almost certain sooner or later to dislodge the worm for which we are seeking (see Fig. 28). When disturbed by the removal of the stone under which it has been lurking in an ill-defined burrow, it swims away with a peculiar wriggling motion. The colour is brown or greenish, and there is usually a faint but distinct metallic sheen. The length may be as much as six inches, but in forms from shallow water it is likely to be considerably less. The upper surface is arched, the lower flat with a distinct median groove, and the worm is uniform throughout its length, tapering towards the posterior end. It is very distinctly ringed, each ring bearing a pair of small lateral outgrowths, or parapodia, which carry bristles. A worm exhibiting these characters is pretty sure to be a species of *Nereis*, and most probably *N. pelagica*. Catch one or two of the largest you can find, and place them in a bottle with seaweed and clean water. They are not easy to keep in confinement, and will probably not live longer than a day or two, but this is long enough to observe some of the habits, the method of swimming, and so forth. If it is not desired to keep them alive, they may be killed at once by dropping direct into methylated spirit or formalin.

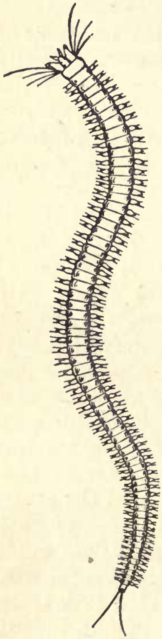

FIG. 28.—*Nereis pelagica.* Note the head, or prostomium, with its small feelers and large palps, and the peristomium behind it with four pairs of cirri, but no feet.

After death, whether this be due to natural causes or to artificial means, you may proceed to your examination. This is most easily done by making at once a drawing of the animal, a practice which should be the invariable rule. The very act necessitates far closer observation than is likely otherwise to be given; the relative slowness of the process impresses the facts firmly upon the memory; the drawing, however rough, forms afterwards a most valuable record of the work done; and finally, in accordance with a familiar psychological rule, the concentration of attention necessary to produce an accurate drawing will intensify a thousandfold the pleasure obtained from your dissection.

As to the details of the process, my own experience is that an artist's sketching-block of small size, where the sheets can be torn off as they are used, is more convenient than a book. The sheets can be kept in a portfolio and arranged in order there, whereas in a book it is virtually impossible to maintain a proper sequence. A water-colour sketch, the parts being as nearly as possible the colours of life, is the form of sketch most likely to produce permanent satisfaction, but where this is impossible a mapping-pen and Indian ink should be used in preference to pencil; pencil drawings on loose sheets being very apt to get blurred. Annotate your drawings fully at the time that they are made, and mark carefully those points about which you are uncertain; in time light will probably dawn. In addition to the careful drawings of the whole animal, a few entirely diagrammatic sketches of the separate parts should be made.

As to the points disclosed by your examination, a *Nereis* is a ringed worm (Annelid), composed of a series of rings or segments, each of which is of similar structure. You may compare it roughly to a railway train, composed of numerous similar carriages linked together. Consider for a moment the railway train as the more familiar object. Its form is obviously an adaptation, as the biologist calls it, to its particular form of movement. As it sweeps gracefully round a curve, you see at once how necessary and suitable its form is, how much the freedom of movement depends upon the yielding linkage. Almost all animals which can move rapidly and gracefully in water, and are of elongated shape, are similarly composed of a series of units. In the language of Biology they are segmented animals, and *Nereis* and its allies illustrate one of the simplest forms of segmentation. A simple form because the component units are similar throughout the body, only the anterior and posterior ends showing slight structural differences. With *Nereis* should be compared, on the one hand, the Nematodes, with their unsegmented bodies and peculiarly stiff method of locomotion, and, on the other, the more differentiated, segmented animals, such as crab and crayfish, where the body-units are no longer all similar, but are adapted to serve different functions.

Let us now examine the segments in detail. Any of those from the median part of the body, taken at random, will show the following points: first, the characteristic shape, rounded above and flattened beneath with a central groove; then the appendages, large lateral outgrowths, forming the *parapodia*, or "feet." Of these each segment bears a pair, and their structure is somewhat complicated (see Fig. 29). Each consists of a dorsal and ventral process, both bearing tufts of stiff bristles. More careful examination by means of a lens will show in addition the following points. Both dorsal and ventral processes are bilobed, and it is the lower lobe of the dorsal and the upper lobe of the ventral only which bear bristles, the other two lobes are mere vascular plates. Further, both processes give off slender sensitive outgrowths, the feelers, or cirri, of which one is dorsal and the other ventral. The bristles have usually a peculiar golden sheen, and in each tuft there is one of needle-like shape which only projects very slightly, but which is easily found on dissection. It is to these needles that the muscles are attached, and they form, as it were, the skeleton of the foot.

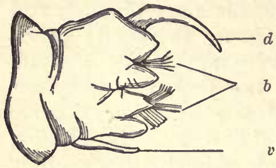

FIG. 29.—Foot, or parapodium, of *Nereis pelagica*. *d*, dorsal cirrus; *v*, ventral cirrus; *b*, bristl s borne on the lobes of the foot. The relative lengths of the different parts, and especially the long dorsal cirrus, are distinguishing marks of the species. After Ehlers.

To recapitulate, the parapodia are hollow, muscular outgrowths of the lateral body-wall; they are divided into bilobed dorsal and ventral processes, each bearing bristles, each giving off a delicate sensitive cirrus. By virtue of their muscles and bristles the parapodia are locomotor organs; by virtue of their contained blood-vessels they are respiratory organs; by virtue of their sensitive cirri they are sense-organs. As one or other of these three functions predominates in the bristle-worms, we have a corresponding variation in the structure of the foot.

If we look now at the anterior region or head, we find that it differs considerably from the other parts of the body. Overhanging the mouth is a dorsal lobe which bears eyes and tactile processes, and is the head proper. The lobe is called the prostomium, and is probably not equivalent to a segment. Surrounding the mouth is the peristomium, or first true segment, which also bears tactile processes, but has no parapodia nor bristles. In most bristle-worms the head region consists of these two parts, but in a few, other modified segments are added to it. This is interesting, because when we pass to Arthropods we shall find that the head consists of a number of segments all firmly welded together.

The head of *Nereis* varies considerably in appearance, according to the condition of the parts, whether fully protruded or retracted. If a large *Nereis* be killed suddenly, as by immersion in spirits, it will be observed to rapidly protrude a large "proboscis" or "introvert," which when completely everted shows at its tip a pair of powerful horny jaws (see Fig. 30). The method of eversion is interesting, and is one which is common among Invertebrates. It is best understood by taking a glove, fastening two pieces of thread about an inch from the tip of one of the fingers to represent the jaws, and then doubling in the finger into the glove as far as it will go (see the upper diagram in Fig. 30). The hole left where the finger is doubled in represents the mouth of the worm, and it will be seen that the little tags representing the jaws (*j* in Fig. 30) now lie well within the mouth-cavity (*m* in Fig. 30); they are not visible in the worm under ordinary conditions. Now carefully double the inturned glove finger outwards until the "jaws" lie just at the tip of the part turned out; this represents the "proboscis" of *Nereis* when fully everted, and then bearing the jaws at its tip. All the part which can be thus everted is called the buccal cavity. It opens into the pharynx (*p* in Fig. 30), the next part of the alimentary canal, which is represented by the remainder of the glove finger, but which differs from it inasmuch as it cannot be everted, or turned outwards, but can merely be protruded with its terminal jaws. The head, therefore, of *Nereis* appears entirely different according to whether the buccal region is retracted or everted. In the former condition the mouth

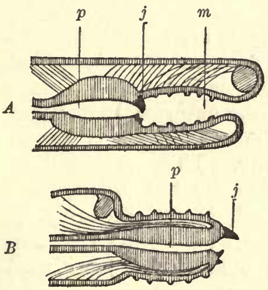

FIG. 30.—Diagrams showing the way in which the proboscis is everted and retracted in *Nereis*. The upper figure (*A*) shows the retracted condition, the lower (*B*) the everted. For letters see text. After Lang.

appears as a wide opening beneath an overhanging lobe, and some little distance from the anterior end of the body. In the second condition it appears at the end of the everted proboscis, bounded by the great jaws, and opening directly into the protruded pharynx, the proboscis itself being merely the anterior part of the alimentary canal in an everted condition. The actual appearance of the everted proboscis with its small teeth is shown in Fig. 35.

We may now pass on to consider the appearance of the head proper. In the living animal, or in the dead animal with retracted proboscis, the mouth is seen to be ventral and overhung by the prostomium. On its dorsal surface the prostomium bears two pairs of eyes, and in addition a pair of very small tentacles and a pair of distinct large processes called the palps (see Fig. 28). The next ring, the peristomium, bears, as we have seen, no parapodia, but only four pairs of long feelers or tentacular cirri, which are used like the feelers of an insect.

Behind this head region the segments are all uniform and similar except the last, which is without parapodia, but bears a single pair of long tactile cirri, or feelers.

Having made out these points in the external anatomy of a typical Chætopod like *Nereis*, the next point is to get some notion of the internal anatomy. This may be done by proceeding at once to dissect *Nereis;* but unless some experience has already been acquired, it will probably be found easier to begin with the fisherman's lob-worm (*Arenicola piscatorum*), which can readily be obtained of large size, and which is exceedingly easy to dissect.

The lob-worm is abundant on most sandy shores, especially in sand which contains a considerable amount of organic matter. It is a sedentary worm, burrowing in the sand, and lining the burrow with an organic secretion, which gives the walls a certain amount of firmness and renders them easily visible when the sand is turned up. It swallows the sand for the sake of its organic particles, and rejects the indigestible residue in the form of the familiar sandy "castings." If these be pushed away the mouth of the burrow can be seen, and the burrow itself may be followed some distance by digging in the sand.

For the purpose of examination and dissection the lob-worm may be obtained by digging in the sand where the castings are abundant. Except by the intervention of a strong arm and a powerful spade, however, the process is not very easy, and the simplest plan is usually to invoke the aid of a fisherman—amateur or professional. The specimens chosen should be not less than seven or eight inches in length, and should be obtained uninjured and in the living condition. The worms have an exceedingly well-developed blood-system, and are full of blood, a fact which, combined with the delicate body-wall, makes it not very easy to obtain perfectly uninjured specimens.

The lob-worm will not be found easy to keep alive for any length of time, but it will live for a day or two if placed in a vessel with wet sand, and there some of its habits can be readily observed. The way in which it moves is especially interesting, but before describing this we must just glance at its external characters (see Fig. 10).

In studying these we are at once struck by the marked contrast with *Nereis*, especially in the condition of the parapodia. Let us recall for a moment the functions of these structures in *Nereis;* they are locomotor, respiratory, sensitive. Now the lob-worm is more or less sedentary, so that we should expect that the parapodia, in so far as they are locomotor organs, will show reduction. Correlated with the sedentary habit we have here, as always, a greater difficulty in breathing, and so we have the development of special respiratory organs, the gills. Again, a sedentary animal has a more limited environment than an active one, and is less likely to have well-developed sense-organs, so that we should expect to find that the parapodia have to a large extent lost their sensitive nature. The first glance at *Arenicola* will show that with loss of function there is also degeneration of structure. Its parapodia are mere rudiments, little tufts of bristles. The characteristic sensitive cirri of *Nereis* seem to be absent, we say seem to be advisedly, for the tuft-like gills in the middle region of the body are in reality the metamorphosed dorsal cirri, which have lost their sensitive and taken on a respiratory function. With the exception of these gills, in reality a specialised portion of the parapodia, the parapodia of *Arenicola* are very greatly reduced, and do not function as locomotor organs.

Having noticed these points, study the movements of the living worm. The body is divided into three regions—an anterior, usually much swollen, region, with lateral tufts of bristles; a median region, with the conspicuous gills and less obvious bristles; and a tail region, with neither bristles nor gills. As it is thus destitute of definite locomotor organs, our first query must be, How does *Arenicola* move? If you watch your specimens closely, you will be struck by a marked and peculiar wave of motion which begins in the gill region, and gradually sweeps forward to the anterior end. This wave produces a very marked distension of the body, and has all the appearance of being due to the passage forward of fluid within the body-cavity. The distension is most marked in the anterior region, and often terminates in the protrusion at the extreme anterior end of a "proboscis," with numerous papillæ on its surface, which is obviously homologous with the "introvert" of *Nereis*. As the wave sweeps forward it will be noticed that the little tufts of bristles are completely withdrawn into the body, which must greatly diminish the resistance to the passage through the sand. As the wave passes any particular spot, it will be further observed that, immediately after its passage, the bristles are protruded to their fullest extent. When the worm is lying on a smooth surface the forward wave is followed by a backward one, during the course of which the animal slips slightly backwards. There can be little doubt, however, that under ordinary conditions the protrusion of the bristles must prevent this, for they will tend to grip the sides of the burrow. The lob-worm thus works its way through the sand as the earthworm does through the earth, and in both cases the bristles are of great importance. The process is a very interesting one, and can be readily watched in a living *Arenicola* lying on wet sand.

The lob-worm, indeed, is of interest in several respects, for it seems to stand half way between the active worms like *Nereis*, and the very passive tube-forming types like *Terebella* and *Serpula*. At one time the Polychætes were divided into two sets—the sedentary tube-builders, and the active free-living forms. This classification is no longer in use, for it is found that many forms not nearly related have independently taken to a sedentary life. Nevertheless, it had a superficial justification in the fact that sedentary forms have certain external characters in common. In *Arenicola* we see, as it were, the first effects of the passive life upon the organism. As the sedentary habit becomes more firmly fixed, the bristles become more degenerate, except when specialised anteriorly to aid in tube-building. At the same time the tube becomes more and more highly developed. It may consist entirely of secretion poured out by the animal, or may be composed of foreign particles glued together by the secretion. This secretion is present to a slight extent in *Arenicola*, where, as we have seen, it gives a certain amount of firmness to the walls of the burrow. In most tube-builders there are on the ventral surface swollen areas, known as "gland-shields," which seem to be of much importance in tube-formation. Though these as such are not distinct in *Arenicola*, yet the ventral surfaces of the segment lines in the middle region of the body are in life much swollen, and are probably of much importance in the production of the secretion used in lining the burrow.

In looking for these glandular regions it will be noticed that in *Arenicola* the body is closely ringed, the rings being more numerous than the bristles which mark the segments.

Having observed these points, the next step is to dissect the internal organs. Pin the animal down on wood or paraffin under water, with the dorsal surface—that bearing the gills—uppermost. An ordinary pie-dish, in which a piece of weighted cork or wood has been placed, makes an excellent dissecting-dish, or a couple of candles may be melted in the pie-dish, and the animal pinned down on the solidified surface. Put the anterior pin in carefully, so as not to injure any of the internal structures. Then take a pair of fine scissors, and slit up the dorsal surface between the gills from the head to a little behind the last gill. Pin out the body-walls, and the dissection should present the appearance shown in the figure.

The first point to be noticed is the large size of the body-cavity, and the absence of transverse partitions, or septa. The large body-cavity is characteristic of bristle-worms in general, but in most of them it is divided into numerous compartments by divisions which correspond to the segments. The absence of these septa is no doubt an adaptation to the burrowing habit, for it enables the body fluid to move freely, and, as we have seen, that has an important bearing in relation to the method of movement. The absence of septa is further correlated with the power of distending the anterior part of the body, which has an important mechanical effect in burrowing.

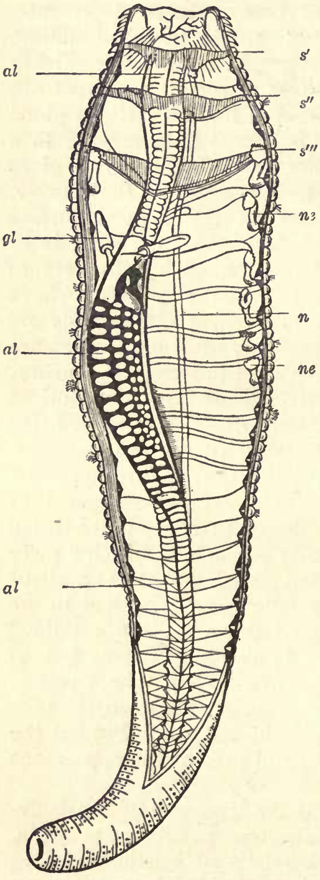

Fig. 31.—Dissection of lob-worm from dorsal surface. For explanation, see text. In part after Gamble and Ashworth.

Running down the centre of the body is the alimentary canal (*al* in Fig. 31), which in most bristle-worms perforates the septa, but which is here almost free in the body-cavity. Not entirely, however, for in the anterior region there are three supporting mesenteries (*s'*, *s''*, *s'''*), and behind the gill-bearing region there are many of these. The anterior mesentery, or diaphragm, is a structure of great interest. It is completely circular, and is attached to the alimentary canal at the point where the protrusible region, or buccal cavity, opens into the next region. During the burrowing movements the body fluid sweeps forward until it is stopped anteriorly by this circular diaphragm. It then exerts a pressure upon the diaphragm to which the latter can yield in one way only—by the protrusion of the introvert, which is doubled outwards by the pressure of the fluid behind. When the wave sweeps backwards again the introvert is retracted, but carries with it a certain amount of sand, which, be it remembered, contains the animal's food. The process of burrowing is thus aided by the removal of part of the sand, while the power of distending the body, especially in the anterior region, facilitates the progress of the animal. This power is associated with the absence of septa, and we thus see how deeply habit affects structure, and therefore how it is that the sedentary forms show such an apparently close relation to one another. It is one of the most difficult tasks of philosophical zoology to distinguish between resemblances in animals which are due merely to adaptation to a similar mode of life and those which are due to common descent.

As to the other structural peculiarities of *Arenicola*, notice the large glands (*gl*) opening into the intestine, the abundant blood-supply to the gills, the ventral nerve-cord (*n*), seen by pushing aside the alimentary canal, and the six pairs of kidney tubules, or nephridia (*ne*), in the anterior segments, which open from the body-cavity to the exterior.

Into the minute points of structure we cannot enter here, but may briefly summarise the salient features of the internal anatomy of a Polychæte worm. All have a large body-cavity, or space between alimentary canal and body-wall, and this is usually divided into chambers by cross partitions. The alimentary canal runs straight down the body, and has anterior and posterior openings (contrast sea-anemones and their allies). There is a ventral nerve-cord, and typically a pair of kidney tubes to each segment, but these are often reduced in number.

In classifying worms the most important points to be noticed are the shape of the head and the nature of the feet, or parapodia, and the bristles. Our British Polychætes are very numerous, so that we can select only a certain number. Those selected are those which are fairly common at most parts of our coasts, and are of sufficient size to be examined and identified with a lens or simple microscope. The more minute forms, though often of great interest, are beyond our scope. Even with this limitation, however, the worms form a difficult group, and their recognition can never be made easy; but their diversity of habitat renders them a group of extraordinary interest. Many of them are exceedingly beautiful both in form and colour, and the habits of the tube-builders make them very interesting pets. Although all are furnished with bristles, which are often large and strong, yet most are greatly relished as food by the carnivorous inhabitants of the ocean. This fact every fisherman knows, and the voracity with which many fish will take a worm bait explains clearly enough why it is that the worms should display so much ingenuity in seeking shelter. Often this shelter is of their own making, as witness the great variety of tubes, from the simple jelly envelope of *Siphonostoma* to the elegant sand tubes of *Pectinaria*, and the limy coils of *Serpula*. Other worms, like *Nereis* itself, form irregular burrows of sand and weed; or seek shelter in rock crevices, roots of weed, and empty shells; or bury themselves deeply in mud and sand. One species of *Nereis* lives inside shells inhabited by the large hermit-crab, and thus probably gets not only shelter but scraps of its host's food. In what respect the hermit is the gainer is less clear. Some other forms live among the prickly spines of sea-urchins and starfishes, in this way no doubt obtaining protection from soft-skinned foes. So varied are the habitats of the worms that to the question, Where should one look for them? the answer may be, Almost anywhere. In sand and mud, under stones and overhanging rocks, among seaweed, wherever shelter and food are to be obtained, the worms may be found. At the end of this and the following chapters will be found tables designed to aid the beginner in naming the common shore worms, but many are not easy to identify.

The first example is one which is, practically speaking, common everywhere on the shore. On lifting up stones on the shore rocks you are certain sooner or later to uncover a little creature about one to two inches in length, which in general appearance is very like a "slater," but which when disturbed wriggles away with a lateral movement of the body which is quite characteristic. It is not very worm-like in appearance, for the rings of the body are covered by flat plates, or elytra, but the bristles which project at the sides of the body quite clearly indicate its real nature. An animal displaying these characters is tolerably certain to be a species of *Polynoë*, and the commonest species on the shore is generally *Polynoë imbricata*, the common scale-worm. If you drop your specimen into a collecting jar you will notice that it wriggles its way downwards through the water, after a fashion which can hardly be justly described as swimming. If you go on with your collecting and re-examine the worm after an interval, you will probably find that the jar contains, in addition to the worm, a number of small flat plates of greyish tint. These are the elytra, or scales, of the worm, and it not infrequently happens that the little creature will throw off every one of these within a very short period of its capture. When these are gone the segmentation of the body is very clearly visible, and the animal looks so different that it may not be recognised as the same creature. Not a few of the shore animals have this power of throwing off parts of their body, apparently on very slight provocation, and in cases like the present the use of the habit is not very obvious.

The Polynoids do not make satisfactory inhabitants of an aquarium, nor do they generally make good preparations, for it is very difficult to get a complete specimen. Nevertheless, a few specimens should be taken, for the animal well repays examination. It is a very abundant and widely distributed species, occurring on both sides of the Atlantic and in Japan. It must, therefore, be very well adapted to the conditions of shore life, though it is not easy to point out the nature of the adaptations.

The following general points should be made out. The body is short, flattened, and has nearly parallel sides. The head has three tentacles and a pair of palps, while the next segment, the peristomium, bears a pair of elongated cirri at each side. The remaining segments are furnished with parapodia of typical form, with dorsal and ventral branches bearing bristles. Now it will be recollected that in *Nereis* the parapodia bear dorsal and ventral tactile processes or cirri. What about the cirri of *Polynoë?* A little careful examination will show you that the ventral cirri are present on all segments, though except in the case of the anterior segments they are short. The dorsal cirri occur in the typical condition on every second segment in the anterior segments, and in the posterior region are missing only from every third segment. When they are absent elytra, or scales, are present, and these elytra are undoubtedly nothing but metamorphosed dorsal cirri. We thus see that though *Polynoë* has so little apparent resemblance to a "worm," yet it is in all essentials of structure similar to *Nereis*. It is a great part of the interest of worms that they show in this way how structures may be modified and metamorphosed to fulfil different functions, and satisfy changed needs. The elytra are hardened, horny structures, and must serve to protect the organism, while they are said also to be sensitive like the unmodified cirri. We shall not consider the structure of *Polynoë* in further detail, but may just notice that like *Nereis* it has a protrusible introvert, in this case furnished with two pairs of horny jaws.

Related to *Polynoë* is the sea-mouse, a much larger and handsomer form, which does not occur on the shore rocks, but is often thrown up after severe storms. In shape it is even less worm-like than *Polynoë*, for it has an oval-depressed body with little sign of segmentation visible externally. Either because of its beauty, or because it may be practically supposed to be born of the foaming breakers which toss it on the beach, it is named after the fair goddess who rose from the waves, and is called *Aphrodite aculeata*. The body is densely covered with bristles and hairs, which form a dense felt over the scales, and at the sides of the body gleam with brilliant iridescence, changing with every changing ray of light. The sea-mouse may reach a length of six inches, but is usually considerably smaller. The peristomium is remarkable because it has shifted in front of the mouth, and bears two typical parapodia—a very unusual condition. The scales number fifteen pairs, as in *Polynoë imbricata*, and are similarly arranged, but they are not visible until the dorsal mass of hairs is removed. The sea-mouse is a very interesting worm, for it combines wonderful beauty of colouring with ugliness of form. It is generally found among weed and rubbish on the shore, and as one turns over the débris its brilliant hues suddenly flash out in all the colours of the rainbow. Partly, as I think, because of the unexpectedness of the colouring, partly because many people have little appreciation of form in the lower animals, *Aphrodite* has always had abundant praise lavished on its beauty. Many people even go so far as to call it the most beautiful of the Polychætes. There is certainly no doubt as to the beauty of colouring, but for my own part I must confess to a preference for some of the leaf-worms, which present a combination of beauties of form, colour, and motion which is denied to *Aphrodite*.

As to the habits there is not much to be said, for the worm lives in mud or sand in deep water, and is not easy to keep alive. Although it might be supposed that the thick coating of bristles would render it anything but a pleasant mouthful, it is nevertheless greatly relished by the cod and other fish, whose stomachs are sometimes filled with fine specimens.

There is another common shore worm which is related both to *Polynoë* and *Aphrodite*, but differs markedly in

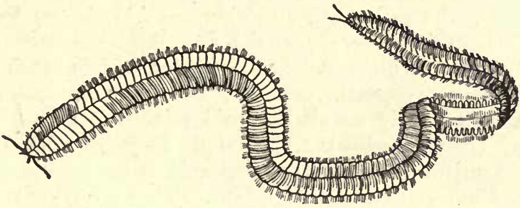

FIG. 32.—*Sthenelais boa.* After Johnston.

appearance from both. This is the common sand Polynoid, *Sthenelais boa* (see Fig. 32), which lives in sand or sandy places. It resembles *Polynoë* and the sea-mouse in having the dorsal surface covered with scales, but differs very markedly from both in its elongated shape and numerous segments. Specimens reaching a length of eight inches are said to sometimes occur, but the usual length is from five to six. The body is flat, narrow in proportion to its length, and hardly tapers at either end, so that the worm looks as if it had been abruptly truncated in front and behind. Though the colours are unobtrusive—quiet sandy greys or browns—yet the size and shape give the worm much greater beauty of form than that displayed by the ordinary squat Polynoids. It is common in most places where there is sand, and may be obtained either by digging in the sand, or, quite as frequently, under stones which are resting on a bed of muddy sand. It does not throw off the elytra quite as readily as the common *Polynoë*, but has almost a worse fault in the tendency to break into pieces on very slight provocation. It has, on the other hand, the great advantage of preserving well, and making a beautiful preparation when once it can be obtained intact.

Some interesting points of structure may be noticed. The scales begin on the second segment, and up to the twenty-sixth segment occur on alternate segments; after this they are borne on every segment. In addition each segment bears two small gills which are covered by the scales. These gills are believed not to be homologous with dorsal cirri, which are here represented only by the scales. The last segment of the body bears two extremely fragile cirri. The worm is sometimes called "brown cat" by fishermen, who call another sand worm (*Nephthys*) "white cat." There is some superficial resemblance between the two, but the "white cat" has no scales, and is much more rapid in its movements.

The next family we shall consider is that of the "leaf-worms" (Phyllodocidæ). The family includes some of the most beautiful of worms, remarkable alike for beauty of form, of movement, and of colour. They owe their name and much of their beauty to the fact that their cirri are converted into leaf-like plates which are used in swimming. These leafy plates are often brightly coloured, green tints predominating in their colouring, and they stand out like oars at the sides of the body. When the animals move a wave of motion sweeps down the long rows of oars, while at the same time the long lithe body sways from side to side. If we add that some forms possess a lovely changing sheen, in addition to the bright colour seen in repose, it is easy to understand that the Phyllodocids are often beautiful indeed.

It is interesting to note some of the differences between their leafy plates and the scales of Polynoids. In the latter the scales are attached by a small area usually near the centre, so that the whole series forms an armature of overlapping scales, the elements of which are capable of relatively little movement. In the leaf-worms the plates are attached by one end only, so as to be freely movable. Both the dorsal and ventral cirri are modified to form these plates, but the dorsal are the larger. Besides serving as locomotor organs, the cirri have another function. When the worms are irritated or attacked, they pour out an abundant jelly-like secretion, which examination shows to be produced by glands on the plates. It is probable that this mucus protects them from some enemies. It is poured out in special abundance when one employs any of the ordinary reagents to kill the worms, and in consequence spoils them very much as specimens. In some species the plates fall off almost as readily as do the scales of Polynoids.

Of the type genus *Phyllodoce* we shall consider two species only, which differ from one another in appearance very markedly. These are the small brown *Phyllodoce maculata*, and the large green *P. lamelligera.* The former, or spotted leaf-worm, occurs freely among the shore rocks, especially among sand. It reaches a length of from three to four inches, but is very slender in proportion to its length, a worm of about three and a half inches long being not more than about one-tenth of an inch broad. It is an active little creature, wriggling over the surface of the sand, or swimming through the water with all its plates in active movement. The colour is not unlike that of sand, being a pale brown with three very distinct dark brown spots on each ring. As in all species of *Phyllodoce*, the head (see Fig. 34) bears four small tentacles near its anterior end, and a pair of distinct dark eyes near its posterior margin. Behind the head proper are three segments more or less fused, and bearing in all four pairs

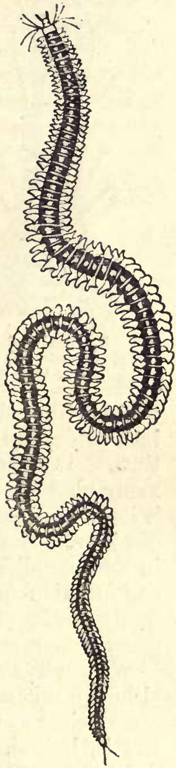

FIG. 33.—Paddle-worm, or *Phyllodoce lamelligera.*

of tentacular cirri. The remaining segments bear parapodia consisting of a single branch, with leaf-like ventral and dorsal cirri. The bristles are relatively few in number. In living specimens you will notice the frequent eversion of the capacious proboscis, or introvert, which has no jaws, but bears small papillæ. This is an extremely common worm, and one almost certain to be encountered. Though the colouring is sober, it is a pretty little creature, and repays careful examination.

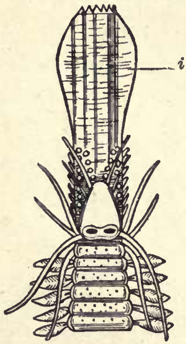

FIG. 34.—Head and introvert (*i*) of *Phyllodoce lamelligera*. After Ehlers.

The other species mentioned, the paddle-worm (*P. lamelligera*), is very much larger, and is one of the handsomest of our British worms (see Fig. 33). It has been known to reach a length of two feet, but is more usually twelve inches or under. It is a bulky worm with a flattened body, usually about a quarter of an inch wide, and is green in colour with iridescent metallic tints. It lives beneath stones near low-tide mark, and in many places is not uncommon. Like the preceding species, it has a capacious introvert furnished with papillæ, but without jaws. The number of tentacles and cirri is the same as in the preceding species, but it differs from this in the shape and position of the dorsal plates. There can, however, be no possibility of confusion between the two species, for their general appearance is very different.

We shall not consider any other species of *Phyllodoce*, although others do occur on our shores, but may just notice some points as to the genus as a whole. It is a large genus, and is, indeed, by some authorities split up into sub-genera defined by the characters of the head, but the specific characters are often very indistinctly marked. In Polychætes in general the characters relied on in discriminating species are usually the numbers and characters of the bristles, the characters of the parapodia, and the structure of the head and introvert when this is present. But in the genus *Phyllodoce*, while some of these points display great constancy, others seem to display much individual variability. Thus, to take one example only, it is believed by some authorities that there are two "paddle-worms," one called *P. lamelligera* and the other *P. laminosa*, while others maintain that these two are one, or are mere varieties of one species. The curious point is that those who regard them as distinct are by no means agreed as to the distinguishing features of each, a fact which certainly suggests the occurrence of variation. Other authorities believe that very many of the so-called "species" of *Phyllodoce* are mere varieties, and that one may, as it were, pick out a few dominant types, round each of which a number of more or less clearly defined varieties group themselves. The point is a very interesting one.

The next genus—*Eulalia*—differs from *Phyllodoce* in the presence of an additional tentacle, so that the head bears five instead of four of these. Curiously enough, however, apart from this prime difference, there is an extraordinary parallelism between the "species" of *Eulalia* and the "species" of *Phyllodoce.* Thus there is a species of *Eulalia* which, except for its tentacle, resembles in almost every respect *Phyllodoce maculata*, while our commonest *Eulalia* (*E. viridis*) has a twin brother in a green *Phyllodoce.* As the extra tentacle in *Eulalia* is often by no means easy to see, there is no difficulty in understanding that this fact has tended to add greatly to the confusion of nomenclature and description, so that the Phyllodocids in general form a very difficult family, and one in which there is still much to be done.

We shall only describe one species of *Eulalia*, and that is the common and beautiful *E. viridis*, the green leaf-worm. It is a small worm, three inches or less in length, of a bright green colour, which is peculiarly vivid in females filled with eggs. It is common in rock crevices at many parts of the coast, and is readily recognised at a glance as a Phyllodocid from the green leafy plates which in life are in constant movement. The fact that it is a conspicuous worm and lives considerably above low-tide mark makes it the most obvious of the Phyllodocids, for *P. lamelligera* is local and *P. maculata* is so slender and inconspicuous as to be readily passed over without notice. In spite of its beauty and fragile appearance, *Eulalia*, like the other Phyllodocids, is a carnivorous animal, living chiefly upon other bristle-worms. It is also of interest because of the beauty of the egg masses which are laid in spring. Everyone must have noticed the little sacs of transparent jelly, filled with minute bright green eggs, which are so common in spring on the shore attached to stones, shells, and weed. In shape they are like very large grapes with a soft jelly stalk. These are the eggs of *Eulalia viridis*, and if you pierce the jelly and examine a few of the freed green specks under the microscope in water, you will probably see the little top-shaped larvæ creating miniature whirlpools by the active movements of their long cilia. These peculiar larvæ occur in the life-history of most bristle-worms, and also of Molluscs. They are active little creatures adapted for life near the surface of the water, and thus are probably important in the distribution of sedentary forms like most of the bristle-worms. At least the early stages of development can be followed in the eggs of the Phyllodocids, and their egg packets are certainly the most conspicuous and the most readily found of the eggs of Polychætes.

It is, perhaps, hardly necessary to describe *Eulalia viridis* in further detail. The fifth tentacle arises far back on the head, between the two eyes, and as in *Phyllodoce* there are four pairs of tentacular cirri, or tactile processes, on the head. The dorsal plates are pointed and elongated, and the ventral similar but smaller. The bright green colour is very characteristic, and makes the worm easy to recognise.

KEY TO WORMS DESCRIBED IN THIS CHAPTER.

Class.—Chætopoda (bristle-worms).

Order.—Polychæta. The bristle-worms of the sea.

Worms with flat scales, or elytra, on their backs.	Fam. Aphroditidæ.	Body short, flattened, with parallel sides—*Polynoë*.
		Body oval and depressed, covered dorsally with a felt of bristles—*Aphrodite*.
		Body elongated and worm-like. Head with three tentacles—*Sthenelais*.

Worms with leafy plates (cirri). Head with four or five tentacles.	Fam. Phyllodocidæ.	Head with four tentacles—*Phyllodoce.* Head with five tentacles—*Eulalia.*

CHARACTERS OF SPECIES.

Fam. Aphroditidæ.

Polynoë. *P. imbricata* has fifteen pairs of scales, which fall off very readily. The projecting bristles have a length equal to half the width of the body.

Aphrodite. *A. aculeata* has fifteen pairs of scales beneath the felt of bristles. There is a small median tentacle and two long palps on the head. The body tapers posteriorly.

Sthenelais. In *S. boa* the head has three tentacles, a pair of long palps, and four eyes. The first segment bears three pairs of cirri.

Fam. Phyllodocidæ.

Phyllodoce. In *P. maculata* the body is very slender, the dorsal plates are rounded. In *P. lamelligera* the body is broad and massive, and the dorsal plates are oval or heart-shaped.

Eulalia. In *E. viridis* the body is bright green, and the dorsal plates are narrow and pointed.

All the worms mentioned in the chapter are widely distributed throughout the British area.

CHAPTER VI.

BRISTLE-WORMS—*continued.*

The Nereids—Formation of Heteronereis—Characters of Heteronereis—The common species and their habits—Two sand-worms, Nephthys and Glycera—Their structure and habits—The rag-worms—The worm Cirratulus—The Terebellids and the process of tube-building—The tube of Pectinaria—Trophonia plumosa—The Sabellids and Serpulids—The tube-building of Sabellaria—The "living film"—Ribbon-worms—Polyzoa.

THE family with which this chapter opens is one containing a number of large and common forms. It is the Nereidæ, to which the genus *Nereis*, described in the preceding chapter, belongs. As intimated there, by far the commonest species, on Northern coasts at least, is *Nereis pelagica*, which occurs abundantly between tide-marks, varying in size from two to six or more inches. It is usually of a fine bronze colour, and is an active and handsome form, showing not a little colour variation. As to the species marks, the easiest way of recognising it is to examine the little teeth, or paragnaths, on the introvert (see Fig. 35), but it is also characterised by the great size of the palps, the elongated shape of the head, the long dorsal cirri, and the arched back. It may be well to notice that in *Nereis* the palps are readily distinguished from tentacles by their shape and size. This is not invariably the case, but the two may always be distinguished by the fact that while

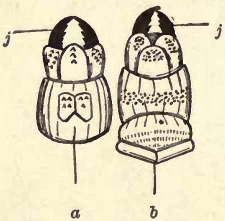

FIG. 35. — Upper (*a*) and under (*b*) surface of the introvert of *Nereis pelagica*; *j*, jaws. The dark specks are the paragnaths, which vary slightly in different specimens. After Ehlers.

the palps arise from the ventral surface, the tentacles are dorsal. Perhaps one of the most interesting things about this, as about most of the other species of *Nereis*, is the changes which it undergoes at sexual maturity. When hunting under stones for specimens you may not infrequently find one which is peculiar in that while the anterior part of the body has all the usual characters, the posterior region is strikingly different in appearance, so that the worm looks as though it were compounded of two dissimilar worms. The colour is also remarkable, for the body is bright green anteriorly, and pure pink in the posterior region. If you examine the posterior region more closely, you will find that the difference in appearance is largely due to the modification of the parapodia. These have greatly increased in size, and their different regions have developed leafy outgrowths, which convert the parapodia as a whole into swimming organs. The resultant change in the external appearance of the animal is so striking that the modified form was for long supposed to belong to a distinct genus, and was called *Heteronereis.* It is now known to be merely the mature form, and owing to the fact that it is adapted for a free-swimming existence no doubt assists in the distribution of the species. It will be remembered that in the Cœlentera the sessile sea-firs bud off active swimming-bells, which produce the ova, and by their power of swimming ensure the distribution of the species. In certain small worms belonging to the genus *Syllis* and to allied genera something quite analogous occurs, for the worms bud off new individuals, which are modified for a free-swimming life, and which contain the eggs and spermatozoa. In another very curious worm, the "Palolo" of Samoa and Fiji, a portion of the body becomes modified, much in the same way as in *Nereis*, but the modified portion separates off, and swims away, leaving, it would seem, the anterior region behind at the bottom. The separated portions of the worm appear at the surface of the water in extraordinary numbers at certain seasons, and are caught and eaten by the natives. The "swarming" only lasts for a short time, and it is probable that the worms die after laying their eggs, while the "heads," which have remained at the bottom among the coral blocks, bud out new bodies, and eventually repeat the whole process. In *Nereis*, though the genital products occur only in the posterior region of the body, this part does not separate off as in the Palolo.

In *N. pelagica* the modifications undergone by the mature female are less marked than those in the male. The female Heteronereids are very much larger than in the male, and have fewer of the segments modified. The modification is also less marked. It is not uncommon to find large specimens with a few merely of the posterior segments undergoing incipient modification. One striking characteristic of both sexes of Heteronereids is the presence of a sensitive rosette on the last segment of the body. Further, in the male the eye increases in size and becomes beautifully coloured, and, as already noticed, the colours in both sexes become brighter. These very interesting changes can be followed very readily on the shore, especially in the North.

Besides *N. pelagica*, two other species occur free on the shore in most places, in addition to *N. fucata*, a handsome species found in shells inhabited by hermit-crabs. The two species are *N. dumerilii*, a rather small form with very long cirri, which forms a tolerably firm tube, and *N. cultrifera*, a large form in which the dorsal cirri are short, and the back less well arched than in *N. pelagica*. Both species occur in situations somewhat similar to those affected by *N. pelagica*, and will be generally found among gatherings of the latter. The distinguishing features are noted at the end of the chapter. To get *N. fucata*, on the other hand, one must collect a few large specimens of hermit-crabs, especially those which occur in whelk shells, and are, therefore, nearly full grown. Such specimens are sometimes flung on the beach by storms, and though often dead or moribund, are at times living and active. If still alive, put your specimens in clean water, and after a time you will not improbably be rewarded by seeing the hermit entirely recover his disturbed equanimity, and sit, metaphorically speaking, at his ease on his doorstep placidly twirling his long feelers. You may further see protruded above the hermit's head the long feelers and stout palps of a brick-red *Nereis*. The worm does not completely quit the shell, but protrudes the anterior part of the body, and no doubt shares in any food which may be going. When the hermit is alarmed and retreats, the worm does the same, and then retires to the topmost whorl of the shell, entirely out of sight. So far does it retreat that it is by no means easy to extract it from a shell quitted by the hermit, and a very vigorous shake is required before the attic tenant will show himself. There is usually only one worm present, but I have found two in one shell. The percentage of cases in which the worm occurs also varies greatly according to the locality; off the Isle of Man it is said to be present in 90 per cent. of the whelk shells inhabited by the hermit-crab, while in other places it is relatively rare. It is not entirely confined to hermit-crab shells, but occurs occasionally free, and occasionally in empty shells.

The living animal is very easily recognised by its colour and markings. It is of a beautiful red tint, with two pure white bands on the dorsal surface. After death, however, the colouring soon fades, whatever the preservative employed. In structure the worm differs from the two preceding in that the parapodia are not all similar, the posterior differing from the anterior. In the posterior segments especially the uppermost lobe of the parapodia is elongated, arched, and swollen. It is highly vascular, and no doubt functions as an efficient respiratory organ.

We shall describe only one other species of *Nereis*, and that is the large and handsome *Nereis virens*. It is a green worm, differing from the other species described in the presence of large leafy plates in the dorsal region of the parapodia. The plates are not expansions of the dorsal cirrus, like the plates of Phyllodocids or the scales of Polynoids, but are expansions of the dorsal lobe itself (cf. *N. fucata*). The structure of the parapodium altogether suggests to some extent the modified parapodia of the "Heteronereis" of other species, and it is interesting to note that though *N. virens* does become converted into a Heteronereis, the changes are relatively slight. The worm reaches a length of over a foot (up to eighteen inches), and when the large black jaws are fully protruded has quite a formidable appearance. It is said to be called the "Creeper," and to be used as bait on some parts of the coast. The leafy plates, like those of Phyllodocids, secrete an abundant supply of mucus which is here used to line the burrow. The worm occurs between tide-marks, and is sometimes to be found by digging near the rocks, while at other times it may be found swimming freely. It is a somewhat local form, but Granton and St. Andrews may be mentioned as places where it is to be found.

It is hardly necessary to enter in detail into the characters of the worm; the size, the colour, and the structure of the parapodia render it easily recognised.

The species of *Nereis* are very abundant on the shore rocks, and are certain to be encountered in shore hunting. With the Polynoids and the Phyllodocids they constitute the commonest and most highly developed of the large free-living worms of the shore. In all three sets the body is very uniform in structure throughout its length, the head is well furnished with various tactile processes, and the parapodia are large and well developed. In studying the bristle-worms, therefore, it is well to become familiar with the common members of these three families before proceeding to the more difficult sedentary forms. Related to these three families are two small families of sand-inhabiting worms, which have much less conspicuous tactile processes on the head, and considerably less brightness of tint. These are the Nephthydidæ, including *Nephthys hombergii*, the "white cat," and the Glyceridæ, including *Glycera capitata*, both interesting and curious worms. Both are genuine burrowers, to be found along with many other worms by digging in sand marked by worm-tracks and burrows. When turned up by the spade both display active movements, during the course of which the enormous introvert is constantly protruded and retracted, with a rapidity which is astonishing, and even alarming to timid people. The performance suggests a juggler's trick, in that the ejected proboscis seems bigger than the worm. In both cases the introvert is an important instrument in burrowing.

The "white cat" (*Nephthys hombergii*) is common in the sand in most places, and is valued by fishermen as bait. The colour is greyish and sandy, but the body displays fine opalescent tints. Usually the worm does not reach a length of more than three to four inches, and it is remarkable in being quadrangular in section. The dorsal surface is flat, and so also is the ventral, save that it has a very distinct median groove. The foot is of remarkable structure (see Fig. 36). When fully protruded the introvert is seen to be furnished with numerous papillæ. There are also two jaws, but these are small and are not protruded. The worm is readily recognised by its opalescent colours and its very active movements, and is a common form which ought to be found and studied.

FIG. 36.—Foot, or parapodium, of *Nephthys hombergii*. *d*, dorsal, and *v*, ventral lobes of foot with bristles and thin plates, *p*; *g*, gill; *c*, ventral cirrus, the dorsal is absent. After Ehlers.

While digging for *Nephthys* one may occasionally turn up an elongated worm with a body which narrows rapidly in the posterior region to form a long tail. The colour is pale yellowish, and the animal has an eminently characteristic habit of coiling itself into a spiral on the slightest touch. The head is extraordinarily long and pointed. An animal displaying these characters is a species of *Glycera*, and the commonest species between tide-marks is *G. capitata*. In most species there may be seen on the dorsal region of the feet in the living worm, small sac-like gills in which the blood corpuscles circulate rapidly, but these are absent in *G. capitata*. The long introvert is crowned by four dark jaws, which in the large *Glycera* of deep water (*G. gigantea*) are strong enough to pierce the skin. The different species are distinguished by the presence or absence of gills, and the minute structure of the parapodia.

The most interesting point in regard to the habits of *Glycera* is the strange way in which it throws the body into a close spiral. Like most sand-inhabiting worms it is not easy to keep alive in captivity.

In the reduction of their tentacles, palps, and cirri, *Nephthys* and *Glycera* lead up to the next genus we shall consider. This is the genus *Nerine* (rag-worms), which includes worms without any trace of palps or tentacles. The peristomium bears a single pair of long tentacular cirri, the dorsal cirri are converted into gills, and the ventral cirri are absent. As compared with any of the preceding worms the parapodia are reduced, and only project slightly at the sides of the body. Both the common species inhabit muddy sand, and both are extraordinarily brittle, breaking into pieces on the slightest provocation. Common as the worms are it is in consequence very difficult to get a complete specimen. The gills (dorsal cirri) are carried curved over the back, and being filled with red blood are in life very conspicuous objects. The tentacular cirri are broad and long, and in life are in constant movement. Like other parts of the body these are very apt to be thrown off by captive specimens. There is little difficulty in distinguishing between the two species. The larger, *N. coniocephala*, is said to attain a length of eight inches, but on the East Coast at least is usually much smaller; the smaller, *N. vulgaris*, is three to four inches long. The larger is the handsomer species, for it is usually of a fine green colour, which contrasts with the scarlet gills. In *Nerine vulgaris* the body is usually yellowish red, but also exhibits a tendency to become green. It will be noticed that the surface of the gills is increased by a membrane (the podal membrane) which extends up the gill, its size differing in the two species. The other distinguishing characters are given at the end of the chapter.

In *Nerine* the parapodia project slightly at the sides of the body, but in the remaining worms they are at most represented by small tubercles bearing the bristles. The worms are almost either burrowers or tube-formers, and very frequently the anterior end, which projects from the tube or burrow, differs markedly from the posterior.

The first of these worms which we shall consider is recommended by its great abundance on the shore rather than by any beauty or great interest. In turning over stones on the rocks, the beginner often tries stones firmly bedded into mud or sand, and therefore without any underlying cavity. When such stones finally yield to a strong pull, they reveal an odorous substratum of mud which is usually traversed in all directions by slender scarlet threads moving about like living worms. A little investigation will show that these are the tentacular filaments and gills of a reddish worm embedded in the mud. If molested the worm not infrequently throws off these filaments, which retain their activity for a long time, and often greatly puzzle the beginner. This worm is *Cirratulus cirratus,* and is often exceedingly common in black sand or mud under stones. In the early part of the year the worms quit the mud, and may be found freely exposed on the rocks in the act of spawning. The eggs are of yellowish colour, and as in most worms are surrounded by a jelly-like substance. As in the case of not a few littoral animals, it is only at the breeding season that one is able to get any adequate idea of the extraordinary number of individuals which occur between tide-marks. In the Firth of Forth in February I have seen the rocks literally covered with the worms, while at other seasons they can only be found by careful search.

It is not necessary to say much of the characters of the worm. The prostomium is long and pointed. Behind it is a transverse row of tentacular filaments, which in life are distinguished from the gills by their paler colour and their "curled" appearance. After death it is not easy to distinguish between gills and filaments. The gills are of course modified dorsal cirri. They are long, slender, and filamentous, and the colour is bright red. They are most numerous and most regularly arranged on the anterior segments; but scattered gills occur throughout the greater part of its length. Apart from the gills, the parapodia are merely represented by papillæ at each side of the segments bearing small bristles. On the East Coast at least the worm does not usually exceed three to four inches in length.

Much more interesting than *Cirratulus* are the Terebellids, or sand-masons, which build long tubes neatly plastered over with particles of sand, shell, and stone. In walking over the sand after the tide has ebbed, one very often finds great masses of the sandy tubes of these worms. Some of these tubes are fringed at the top with branched sandy threads, so curious in appearance that the inexperienced commonly regard the tube as some kind of an animal. These are the empty tubes of *Terebella conchilega,* the sand-mason, and sometimes occur on the shore in extraordinary abundance. They are always empty, however, and usually not more than a few inches in length. We need not, therefore, mourn the untimely decease of innumerable worms, for it is only a portion of the house which has been sacrificed to the force of the breakers; and the worms are tireless "masons," and can soon repair the damage. To find them living we must seek those sandy stretches which sometimes occur among the shore rocks. Here we find the tubes sticking up vertically from the sand, with their stiff fringe and about an inch of tube above the level of the sand. It is easy to imitate the action of the breakers and pull up the tube; but the prudent worm has learnt its lesson well, promptly retreats to the bottom of its tube, and leaves you with a few inches of empty tube in your hand. The worms often measure as much as ten inches in length, and the tubes are always longer, often much longer, than the worm. It is in consequence a somewhat difficult process to obtain a complete specimen, especially when we add to the other difficulties the fact that the worms are exceedingly fragile, and often rupture at a touch. One habit, however, aids the process of extrication. The worms show a marked preference for rock crevices, and in jointed rocks often occupy the widest of the joints. Such jointed rocks are often easily split into blocks, and in this way, with the help of a geological hammer, it is sometimes possible to get very fine specimens. There are a considerable number of Terebellids to be found on the shore rocks, and many of these do not burrow so deeply as *Terebella conchilega*, and may be more easily obtained, but we shall confine our description to this handsome species.

Let us suppose, then, that your excavations have been crowned with success, and an intact specimen of the desired worm lies before you (see Fig. 37). The colour varies, but is often a beautiful rosy tint, the tufted gills being a bright scarlet. The head bears numerous long tentacular filaments like those of *Cirratulus*, which in life are protruded from the opening of the tube. They collect the sand grains and other particles which when mixed with secretion form the tube, and are sheltered and perhaps protected by the stiff fringe of the tube. The first segment (peristomium) forms a bilobed lower lip which is used as a trowel to plaster the tube. As might be expected from the tube-dwelling habit the gills are confined to the anterior segments, where they can be freely exposed to the purifying action of the water. They further differ from those of *Cirratulus* in being branched and comparatively short. Some other adaptations to life within a tube are almost equally obvious. Thus the parapodia are greatly reduced, and the bristles modified so as to suit the needs of a tube-inhabiting worm.

On the anterior segments, from four to twenty-one, there are in all seventeen pairs of papillæ bearing fan-shaped tufts of bristles. The papillæ represent the dorsal lobes of the parapodia, and are absent from the narrow posterior region of the body; they no doubt assist the animal in moving up and down its tube. The ventral lobes of the parapodia are represented by elongated vascular bands at the sides of the segments, each of which bears from eighty to one hundred minute hooks. These hooks are modified bristles and are present in various forms in the majority of tube-inhabiting worms. Very little observation on the rocks will acquaint you with the fact that in most cases a tube-inhabiting worm can withdraw into its tube on an alarm with extraordinary rapidity. In a worm like *Terebella* the process is assisted by many thousands of hooks, each bearing secondary teeth. The hooks are very small, and can just be made out in a good light with a strong lens.

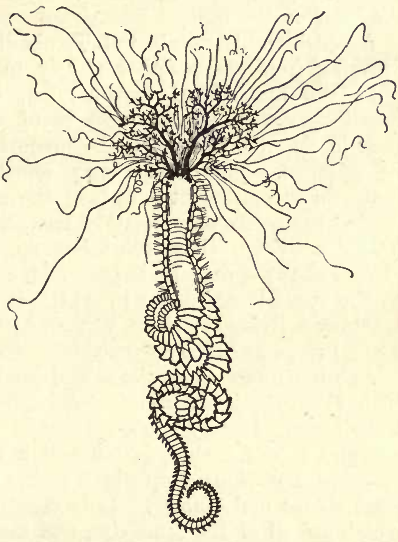

FIG. 37.—*Terebella* removed from its tube. Note the long tentacles, the tufted gills, and the difference between the anterior and posterior regions of the body.

Their presence may often be demonstrated even when they cannot be seen, by drawing a needle over the hook-bearing area, when a slight grating sound will be heard. Unlike the dorsal bristles these ventral hooks occur throughout the body, except on the extreme anterior segments. In the anterior region in the living worm it will be found that the ventral surface is very bright red in colour, and glandular looking. This is due to the presence of fourteen to twenty pairs of "gland-shields," which secrete the mucus which is the basis of the tube.

A considerable number of Terebellids live on the shore, differing from one another chiefly in the structure of the gills, the number of dorsal lobes, of gland-shields, etc. Small specimens of *Terebella* or of others will live for a time in confinement, when the process of tube-building can be watched. The worms may sometimes be induced to build an incomplete tube along the side of the aquarium, so that the worm may be watched through the glass within its tube. Like other tube-inhabiting forms, *Terebella conchilega* shows considerable power of adapting its "masonry" to the special conditions in which it may be placed; thus specimens living in deep water construct tubes which in several respects differ from those of shallow-water forms.

Another interesting tube-worm, smaller and less abundant than *Terebella*, is *Pectinaria belgica* (see Fig. 38), which is to be found in sandy pools. Its tube is short, usually about one and a half inches, is without a fringe, but displays a neatness of workmanship which makes the tubes of *Terebella* seem coarse and clumsy. It is constructed of sand grains, which are all of the same size, and are smoothly and evenly worked into a plaster of mucus, so as to form a beautiful mosaic. The tube is firm enough not to collapse when the tenant is removed, and is open at both ends. The large end corresponds to the head of the worm, but it is this end which in life is buried in the sand, the narrower posterior end projecting from the surface of the sand. The worms live well in captivity, and the habits may be readily observed in specimens placed in a glass jar with clean water and a layer of sand. In such specimens you should see a beautiful crown of golden bristles (*b* in Fig. 38) protruded from the large end of the tube, and used as a trowel to excavate a hole in the sand. If the burrowing occur near the glass, the short tentacles (*te*) will be seen in addition to the golden bristles. When removed from its tube, the worm is seen to be short and stout, with relatively few segments, and a peculiar terminal plate (*tp*), which serves to close the posterior end of the tube. The prostomium bears tentacles like those of *Terebella*, and is much less conspicuous than the peristomium, which carries the bristles, and projects in the form of a collar. There are two pairs of gills (*g*). As in *Terebella*, the parapodia (*p*) are represented by dorsal clusters of bristles and ventral hooks. The worms do not quit their tubes except at the approach of death, but are capable of some amount of locomotion, carrying their tubes with them. In *Terebella*, on the other hand, the tubes are permanently fixed in one spot.

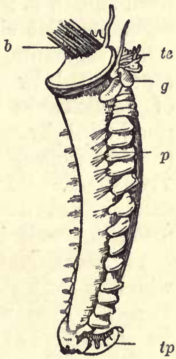

FIG. 38.—*Pectinaria belgica* removed from its tube. For explanation of letters, see text. After Malmgren.

Very different from *Terebella* or *Pectinaria* is the fisherman's lob-worm (*Arenicola piscatorum*), whose appearance and habits we have already described. It is abundant in most suitable places, except where incessant persecution has almost exterminated it, and as bait has, or had, considerable importance to fishermen.

Though we have necessarily omitted many not uncommon shore worms, there is one interesting if inconspicuous worm which deserves special mention. This is *Trophonia plumosa*, which is found not infrequently in muddy places on the shore rocks. It varies in length from two to four inches, and is a Northern form, which is both more abundant and reaches a greater size in the Northern than in the Southern waters of our islands. At first sight it may seem both an uninteresting and a puzzling form, for there is almost nothing in the external appearance to take hold of. The colour is a dull drab, and the only striking character is the great projecting sheath of bristles at the anterior end. Nevertheless the worm is interesting enough. The head is usually retracted, but when protruded it is seen to bear two long tentacles, pinkish or yellow in colour, and eight short gills coloured by the green blood which they contain. The great head sheath is formed by the dorsal bristles of the anterior segments, but similar though shorter bristles occur on the other segments. The ventral parts of the parapodia are represented by projections bearing curious hooked bristles of remarkable structure. The surface of the skin is roughened by numerous papillæ, which in an allied form (*Siphonostoma*) secrete a jelly-like investment absent in *Trophonia.* So far as my experience goes, it is a sluggish animal, not displaying much activity of any kind, but nevertheless it is zoologically full of interest.

The next family to be considered is that of the Sabellidæ, which includes a large number of common and beautiful worms. They usually construct tubes of sand or mud, and are characterised by the presence of a "crown" of beautiful gill filaments. These are formed by the splitting up of the palps, and are of a beautiful green colour owing to the contained blood. The base of the crown is concealed by the peristomium, which forms a projecting collar. As in Terebellids the parapodia are represented by bristles and hooklets, but the hooklets are ventral in the anterior nine segments (thorax), and dorsal in the posterior segments (abdomen). We cannot describe even the more common Sabellids, but may take as an example *Dasychone bombyx*, a worm which is easily recognised by the eyes on its gills. It forms a soft mucoid tube impregnated with particles of sand or mud, and attached to shells or stones. The worm is short (1–1½ inches), of a reddish brown colour, and furnished with a beautiful crown of light-coloured gill filaments. When examined with a lens these filaments are seen to bear dark-coloured eyes, arranged in pairs along the dorsal surface of each filament. Owing to the presence of these eyes the worm is extraordinarily sensitive to variations in intensity of light, and disappears into its tube like a flash if a shadow falls on it. Like other Sabellids the worm, if it can be kept alive, is a most delightful inhabitant of an aquarium, where it may be watched protruding its lovely crown from the tube, so that all the filaments are bathed with water.

Closely related to the Sabellids are the Serpulids, which differ from them in possessing a limy tube which can usually be closed by an operculum, and in the presence of the so-called "thoracic membrane," which is a delicate membrane at either side of the thorax used in smoothing the inside of the tube. There are a great number of Serpulids just as there are of Sabellids. The conspicuous white limy tubes are very common objects on shells and stones, both on the rocks and among the wreckage flung on the beach, and are familiar to most people, but the worms themselves are less well known. In deep water *Serpula* itself is very common, but on the shore rocks a form called *Pomatoceros triqueter* is the most frequent. Notice the distinct keel which runs along the dorsal surface of the tube, and ends in a distinct spine overhanging its opening; then select a few of the largest specimens you can find, and place them, with the shells or stones to which they are attached, in a vessel with clean water. After a period of patient waiting you will see a crown of brilliant gills protruded, whose white ground colour is relieved by splashes of crimson, orange, or blue. As the filaments separate out in the water, notice that, as in Sabellids, they arise in two clusters. Note further that in one of the clusters the filament nearest the mid-dorsal line is converted into a stopper, or operculum, borne on a stalk. The corresponding filament at the other side is aborted. If the worms be not alarmed, they will protrude themselves far enough to show a collar like that of a Sabellid, and the wavy thoracic membrane. In the thoracic region a blue tint usually predominates. By carefully breaking the tube it is possible to remove the worm without injury, so as to display the whole body. Note then the general resem-

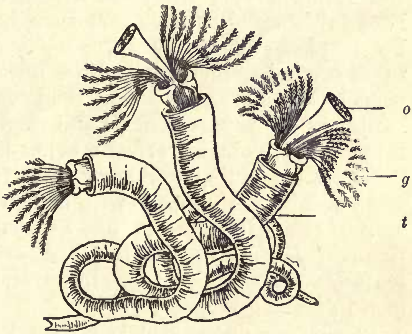

FIG. 39 —*Serpula vermicularis* within its tube. *o*, operculum; *g*, gills; *t*, tube.

blance to a Sabellid, and also the character of the operculum.

Two other common Serpulids may be named without description. These are the tiny *Spirorbis*, which forms its coiled white tubes on *Fucus*, and is often very abundant, and *Filigrana implexa*, a social form whose narrow, interlacing tubes are often very conspicuous on the shore rocks.

The last worm we shall describe is *Sabellaria alveolata*, a curious and interesting form often very abundant on the shore. It is not closely related to the preceding worms, and forms a very firm but irregular sandy tube. These hard tubes are sometimes found singly on shells and stones, but in places where the worm really flourishes, numbers of tubes occur together, so that the worms build up blocks of what looks like coarse porous sandstone. These blocks are hard, and the worms delicate and fragile, so that it is by no means easy to obtain perfect specimens.

Before examining worms removed from the tubes, watch some uninjured specimens within their tubes. They will be seen to protrude from the tube a crown of bristles, similar to those of *Pectinaria* but less brilliant, and also numerous tentacles. The tubes differ, however, from those of *Pectinaria* in being quite immovable.

In the specimens removed from their tubes notice that the body is sharply bent, so that the posterior region with its terminal aperture lies at the opening of the tube close to the mouth. The worms are not more than an inch long, and the anterior thickened region is usually of a bright purplish tint, while the narrow reflexed posterior region is paler in colour. The peristomium has grown right forward over the head and bears the prominent bristles. The prostomium, as in Sabellids, bears numerous gill filaments, but in addition there are dorsal cirri which act as gills (cf. Terebellids). There are many other structural peculiarities too difficult to be discussed here, but the hardened masses of tubes, the purple colour, and the peculiar shape are so characteristic that there is little difficulty in recognising the worm.

In concluding this survey of the bristle-worms it may be well to point out that their great abundance makes it very difficult to mention more than a few representative forms. They occur everywhere on the rocks, and are adapted for all sorts of lives, but as most are relished as food by the larger shore animals so most either form tubes or burrows, or seek convenient lurking-places. Though some, like the Phyllodocids, can swim with ease, in the general case the bristle-worms when they possess any power of locomotion are creepers, using their parapodia as feet. The purely sedentary forms live on minute microscopic particles, found in water or in sand, but the active jaw-bearing forms are carnivorous. In the resting condition the jaws lie far back in the buccal cavity, but when in use they, with the buccal sac, are rapidly everted, and can be as rapidly withdrawn. The beauty of colouring and of form we have already frequently emphasised.

In view of the frequent difficulty of identification a few notes on likely habits for the different species may be welcomed. In rock crevices, or under stones which roof in a cavity, one may expect the paddle-worm (*Phyllodoce lamelligera*), the green leaf-worm (*Eulalia viridis*), the creeper (*Nereis virens*), and other species of *Nereis* (*N. pelagica*, *N. cultrifera*, etc.). But for these smaller species of *Nereis* the most likely spots are roots of *Laminaria*, where many other worms also occur. Under stones resting on sand one finds species of *Polynoë*, *Phyllodoce maculata*, *Sthenelais boa*, and *Trophonia plumosa*; but *Phyllodoce maculata* and *Sthenelais* are as common in sand itself. Stones resting on mud form favourite lurking-places for *Cirratulus*. By digging in sand one may obtain *Arenicola*, species of *Nephthys*, *Glycera*, *Nerine*, as well as other forms. Of the tube-dwellers, the numerous Terebellids, the curious *Sabellaria*, and the comb-worm (*Pectinaria*) all form their houses of sand. The Sabellids have usually tubes made of mud, while the Serpulids make white limy tubes. The exceptional habitat of *Nereis fucata*—within the shell of the hermit-crab—should also be noticed.

As already noticed, apart from the bristle-worms, other "worms" occur on the shore rocks. A few only of these can be mentioned. There are first some interesting leaf-like flat worms known as Turbellaria, of which a common example is *Leptoplana tremellaris*, the "living film." It is a charming little creature barely an inch in length, of a delicate brownish tint, and so thin that it is really a mere film. It is not uncommon under stones on the shore, but requires a trained eye to distinguish it. When turning over stones in search of worms it may be that on the upturned surface, among sponges, tunicates, and what not, you are struck by a delicate film which glides over all obstructions with the smooth movement of a drop of water over a polished surface. Slip a blunt knife carefully beneath it, and drop it into your collecting-bottle. You will notice that it swims through the water by vigorous flaps of the body, with a motion which has been compared to that of a skate. As it settles again on the edge of the bottle, notice with a lens that the mouth is on the mid-ventral surface, and that the greatly branched alimentary canal is visible, ramifying throughout the greater part of the body. There is no distinction in appearance between anterior and posterior end, except that the anterior is furnished with little black specks—the eyes. The little creature will live for a time in captivity, and the grace of its movements makes it a charming inhabitant of the aquarium. The details of structure are too difficult for our purpose, but the animal is worth mention, if only on psychological grounds. It is far from uncommon, and yet many diligent shore hunters never find it at all. If, therefore, you find no difficulty in obtaining specimens, you may flatter yourself that you have acquired the first essential of a shore naturalist—quick observation.

Sometimes associated with Turbellaria are another set of flat worms, the Nemerteans, or ribbon-worms. Many of these occur on the shore, but we shall limit ourselves to two—the pink ribbon-worm (*Amphiporus lactifloreus*) and the great sea-snake (*Lineus marinus*). Under stones at all parts of the shore one may find the pink ribbon-worm, living in a slight tube made of sand cemented together by mucus. It is one to two inches in length, but is extraordinarily contractile. From a bristle-worm it differs markedly in the absence of bristles or any sign of segmentation. In the head region the eyes will be noticed, and also two slits at either side of the head. These are eminently characteristic of the ribbon-worms in general. So also is the so-called proboscis, a slender thread which the worm may be seen to protrude from a pore above the mouth, when alarmed or injured. The worm is very common, and though not particularly active in its movements, is an interesting little creature.

The big sea-snake (*Lineus marinus*) is usually only to be found far out on the rocks near low-tide mark, but is there common enough. It is a splendid animal, varying in length from about three feet up to many yards, but not much thicker than the boot-lace to which fishermen compare it. The colour is usually said to be black, but in reality in life is a beautiful changing purple, soft and velvety in tint. The animal, like all its allies, is somewhat slimy, and has a habit of coiling itself in strange knots, but it is nevertheless exceedingly beautiful. Readers of Kingsley's *Glaucus* will perhaps protest at the adjective, remembering the pages of energetic vituperation which the author hurls at the unfortunate animal, but I cannot think that anyone who studies it without prejudice can fail to be struck by the beauty of the animal.

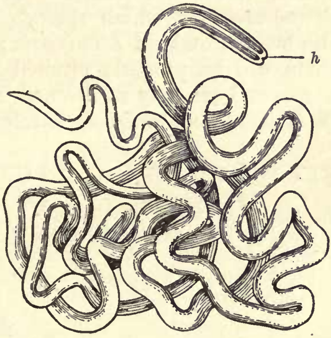

FIG. 40.—*Lineus marinus*, the sea-snake. *h*, head with slits.

Like other ribbon-worms, *Lineus* has head-slits at the sides of the head, and a long proboscis. It lives well in confinement, but usually conceals itself under stones, or in sand agglutinated by its own secretion. Like all its allies, it is extremely brittle, breaking into pieces on the slightest provocation. It is in consequence very difficult to obtain perfect specimens for preservation.

The last group of "worms" we shall mention is the Polyzoa—curious, much modified forms, which live in colonies, and are not unlike "zoophytes." The commonest is *Flustra*, the sea-mat, which is very common in a dry state on the beach, and is often called a seaweed. These dried specimens are in reality merely the houses of the dead worms. A close examination of a piece of sea-mat will show that it is made up of very numerous whitish cells or chambers, each of which once contained a worm. Living Polyzoa are quite common on the shore rocks. Among those to be found there in the active condition may be mentioned *Flustrella*, which forms a soft brownish encrustation on the stalks of *Fucus*, and has its surface covered by numerous spines; *Membranipora*, which spreads like delicate lacework over the broad fronds of *Laminaria;* and many others. None of them can be properly studied without the aid of a microscope, and are only mentioned here because they are sure to be encountered, and may puzzle the student.

KEY FOR IDENTIFICATION OF COMMON BRISTLE-WORMS.

A. Anterior region with well-developed tactile organs. Parapodia well-developed locomotor organs, usually with dorsal and ventral cirri.

B. Anterior region with few tactile organs, often with numerous respiratory organs. Parapodia reduced, cirri absent, or dorsal cirri represented by gills.

A.

Dorsal cirri expanded . .	. .	Aphroditidæ, Phyllodocidæ	See previous chapter.
Dorsal cirri form filamentous sensory organs .	. .	Nereidæ .	*Nereis.*
Dorsal cirri absent or indistinct .	Prostomium short. Gills between lobes of parapodia . .	Nephthydidæ	*Nephthys.*
	Prostomium long, Gill when present dorsal .	Glyceridæ .	*Glycera.*

B.

Head without appendages. Prostomium fused to peristomium .	. .	Arenicolidæ .	*Arenicola.*
Prostomium without appendages, peristomium with two tentacular cirri. Gills curved over back . .	. .	Spionidæ .	*Nerine.*

Prostomium without palps, tentacles present or absent. Gills filamentous or branched	Gills filamentous, numerous	Cirratulidæ	*Cirratulus.*
	Gills branched, segments numerous	Terebellidæ	*Terebella.*
	Gills branched, segments few, anterior crown of bristles	Amphictenidæ	*Pectinaria.*
Prostomium with palps and numerous tentacles (gills). Anterior bristles forming a cage for head.	. . .	Chlorhæmidæ	*Trophonia.*
Prostomium with palps split up to form a branchial crown. Peristomium forming a collar	Tubes of sand or mud	Sabellidæ	*Dasychone.*
	Tubes limy	Serpulidæ	*Pomatoceros.*
Prostomium with palps split up to form rows of filaments. Peristomium forming a hood edged with bristles	Tubes sandy, aggregated	Hermellidæ	*Sabellaria.*

CHARACTERS OF SPECIES.

Fam. Nereidæ.

Nereis. In *N. pelagica* the back is strongly arched, the palps are long, the peristomium or first segment is twice as long as the second. In *N. dumerilii* the cirri are very long; the longest of those borne on the peristomium reaches to the fifteenth segment. In *N. cultrifera* the dorsal cirri are short and the back flattened. In *N. fucata* the posterior feet differ from the anterior, and have a long, arched dorsal lobe. In *N. virens* the dorsal lobes of all the feet bear large leafy plates.

Fam. Nephthydidæ.

Nephthys. In *N. hombergii* the head is pentagonal, with four minute tentacles; palps are absent. The peristomium has a rudimentary foot and a cirrus, but otherwise there are no dorsal cirri. Lobes of feet widely separated, with curved gill between.

Fam. Glyceridæ.

Glycera. Prostomium in *G. capitata* is very long, and bears four minute tentacles at its tip, and a pair of minute palps at its base. There are no gills. The dorsal cirrus is reduced to a mere knob, and the ventral is small.

Fam. Arenicolidæ.

Arenicola. In *A. piscatorum* there are thirteen pairs of gills, and a gill-less tail region behind these.

Fam. Spionidæ.

Nerine. In *N. coniocephala* the prostomium is conical, in *N. vulgaris* it is T-shaped.

Fam. Cirratulidæ.

Cirratulus. In *C. cirratus* a transverse row of tentacular filaments occurs immediately behind the head. The gills are present chiefly in the anterior region.

Fam. Terebellidæ.

Terebella. In *T. conchilega* there are three pairs of gills placed on segments two to four, and fourteen to seventeen pairs of red gland-shields on the under surface.

Fam. Amphictenidæ.

Pectinaria. In *P. belgica* the tube is straight. There are two pairs of gills.

Fam. Chlorhæmidæ.

Trophonia. In *T. plumosa* there are two long tentacles and eight short gills on the head, which is inclosed in a "cage" of bristles.

Fam. Sabellidæ.

Dasychone. In *D. bombyx* the back of the gill-filaments bears distinct dark-coloured eyes.

Fam. Serpulidæ.

Pomatoceros. In *P. triqueter* the operculum is limy, and bears at the sides two horny processes.

NOTE ON DISTRIBUTION.

Perhaps one of the most striking points in regard to the distribution of the worms mentioned is the great size and abundance of *Nereis pelagica* on the North-east, and its comparative rarity and small size on the South and West. On the other hand, *Nereis dumerilii* is much larger on the West Coast than on the East, and is apparently more abundant on the former coast. The Sabellids are perhaps commoner between tide-marks on the South and West. Generally, however, the worms mentioned are widely distributed round our coasts, subject to local variation dependent on food-supply, suitable localities, and so on.

CHAPTER VII.

SEA-URCHINS, STARFISH, AND BRITTLE-STARS.

General characters of common starfish—The characters of Echinoderms and the classes—The starfishes and their colour varieties—The brittle-stars and their peculiarities of structure—The sand-stars—Methods of preserving starfish and brittle-stars—The sea-urchins—Characters of regular urchins—Structure of the shell—Internal anatomy—The heart-urchin, its habitat and structure—Contrast with regular urchins—The Holothurians—Cucumaria and Synapta—Development of Echinoderms.

IN the present chapter we shall be concerned with a very interesting group of animals which are singularly well defined, and not closely related to any others. Some of the general characters of the Echinoderms have already been noticed, others will appear during the course of a preliminary examination of the common starfish, or five-finger. This is to be found in abundance on the shore, especially in the vicinity of mussel beds. It feeds on bivalves of various kinds, and does great damage to mussel and oyster beds. In the neighbourhood of these it grows to a great size, specimens measuring a foot from tip to tip of opposite rays not being uncommon; but on the shore rocks, away from such an extensive food-supply, the usual size is much less. In collecting specimens for examination, you are certain, sooner or later, to encounter individuals strikingly different from the normal. They may have one large ray and four small, or any combination of small and large rays. These illustrate one of the striking peculiarities of the Echinoderms—their capacity for regenerating lost parts. In many cases, notably in the brittle-stars, the animals throw off portions of their bodies when attacked; in other cases, though the animals do not practise self-mutilation to any extent, they possess an extraordinary power of repairing accidental injuries.

Having collected some specimens of the common starfish and placed them in sea-water, the external characteristics can be readily made out. The fact that there are five rays is very obvious, as is also the prickly skin, the ventral mouth, and the five grooves which radiate from the mouth and contain the transparent tube-feet. When the starfish is lifted up from the surface to which it is adhering, it will be noticed that it is attached to this surface by the tube-feet, which end in suckers. So firmly do the suckers cling that it often happens that when the animal is removed from the rock, some of the tube-feet break through rather than let go. When the animal is held in the hand it is easy to feel the limy plates in the skin, and a dried skeletonised specimen picked from the beach will show you the beautiful arrangement of ossicles, or limy plates, which bound the ventral groove along which the tube-feet lie. On the dorsal surface notice between two of the rays a white plate, called the madreporite, or rose-plate, which is perforated by numerous holes through which the sea-water enters the system of canals which supplies the tube-feet. These become tense or flaccid according to the amount of fluid they contain, and being alternately fixed and loosened, serve not only for attachment to rock surfaces, but also for leisurely progression. This may occur in any direction, for the starfish being radially symmetrical like a flower, or a sea-anemone, has no head—no specialised region which always moves foremost. The radial symmetry (usually based on the number five), the limy skin, the peculiar tube-feet, which are part of the "water-vascular" system, the power of regeneration and frequently of self-mutilation, comprise the most obvious of the external characters of the Echinoderms. There are five living classes :—

1. Starfishes (Asteroids).
2. Brittle-stars (Ophiuroids).
3. Sea-urchins (Echinoids).
4. Sea-lilies (Crinoids).
5. Sea-cucumbers (Holothurians).

But of these the sea-lilies only occur in deep water, mostly only in the great depths, and the sea-cucumbers are rare between tide-marks, at least on the East Coast; so that practically our studies of the group must be confined to the starfishes, brittle-stars, and sea-urchins. Even of these we have very few littoral species, so there should be no difficulty in learning to recognise all the common forms. We may conveniently begin with the starfishes, in which the body is distinctly star-shaped, but has often more than five arms, has an open *ambulacral* groove (or groove containing the tube-feet) on the ventral surface of each arm, or ray, and has both the digestive and the reproductive organs prolonged into the stout arms.

The common starfish, *Asterias rubens*, is perhaps the most abundant form, and we may describe its peculiarities first. As in most shore Echinoderms the colour is very variable—red, orange, purple being the commonest tints. The limy plates in the skin are netted, or reticulate, and bear numerous small spines. A row of these spines runs down the middle of each arm, but in very large specimens this regularity of arrangement is not obvious near the ends of the rays. Scattered among the spines are *pedicellariæ*, or little stalked forceps. The tube-feet are arranged in four rows, and the sides of the ambulacral groove are furnished with two rows of spines. To the outer sides of these spines there are three rows of closely crowded spines. We have already noticed the frequent occurrence of specimens showing regeneration of lost or injured parts. In some places this starfish is extraordinarily common, and occurs in numbers in every rocky crevice. St. Andrews and Joppa may be specially mentioned as spots where I have found it very abundant. On the West Coast there occurs, in addition, the larger and handsomer *Asterias glacialis*, which has larger and more numerous spines, arranged in several regular rows down the arms; but this does not occur on the East.

Almost equally common with *Asterias rubens* is another smaller five-rayed starfish which occurs in many colour varieties—purple, purplish red, pure red, orange, all being common. It is more compact in shape than the common starfish, and contains so much lime that it is exceedingly stiff and does not droop flaccidly when lifted up as that animal does. This is *Henricia sanguinolenta*, and it has also a distinctly reticulate or netted skeleton, with minute spines on the meshes of the net. Between the meshes there are in some places pores through which little sacs, or skin-gills, can be protruded. The rays taper very gradually, and have a very narrow ventral groove with two rows of tube-feet. At the sides of the groove there are dense rows of small spines. The species is interesting because it extends over a very wide area, not only horizontally but also vertically; for it lives from the shore down to great depths. About two to four inches from ray to ray may be given as a common size for shore specimens, though the animal does grow to a much larger size. It is very variable, varying greatly not only as to colour, but also as to the degree of development of the spines, and even the number of rays. It is not uncommon to find four- or six-rayed specimens, though normally the number is five.

Our list of littoral starfishes is so short that when we have named the sun-star (*Solaster papposus*, see Fig. 41), we have named all that are likely to occur in the living state between tide-marks on the East Coast. Our common sun-star reaches a large size, and may be recognised by the fact that it has twelve or more rays. Like so many starfishes, it varies greatly in colour—usually purplish red blotched with white, it is sometimes pure red, and sometimes orange. The dorsal surface is covered with peculiar spines of large size, which are separated by spaces through which the little skin-gills emerge in life. Each of these dorsal spines consists of a pillar, bearing at its top a cluster of crowded spines, pro-

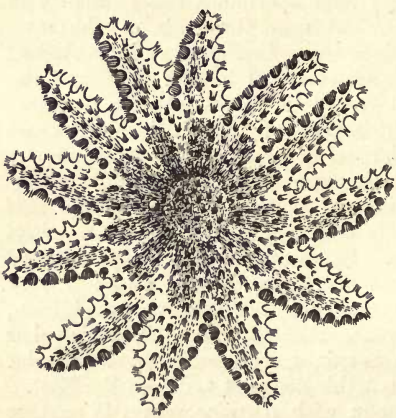

FIG. 41.—*Solaster papposus*, or sun-star. Note the round madreporite to the left of the central disc.

ducing the appearance of a little brush. At the sides of the short rays there are prominent lateral spines of simple structure. There can be no difficulty in recognising the sun-star, but it is interesting to notice how it differs from another species, *Solaster endeca*, which is sometimes flung on the beach by storms. This has nine to eleven arms, is usually purple, not purplish red, has more numerous dorsal spines more closely packed together, and less distinct lateral spines.

After the starfishes we come to the Ophiuroids, or brittle-stars, which from their shape and habits are perhaps less conspicuous than the starfishes, but are quite as abundant. They are to be found under stones or among weed, twining their long snaky arms about the surrounding objects, and snapping them off at a touch. At least three species are common in the living condition between tide-marks, and others occur at times after storms. Instead of giving a formal definition of the group, let us look at the general characters of our common brittle-star (*Ophiothrix fragilis*, see Fig. 42). It is especially abundant among the roots of oar-weed, and a few specimens should be extricated with care and put into clean water. Notice first the much greater activity than that displayed by starfish; it is often difficult to say whether a specimen of the latter is alive or dead, so limp and flaccid does it appear even when taken fresh from its pool. The brittle-star, on the other hand, is continually wriggling its arms, and can progress rapidly by their means at a rate which has been estimated at about

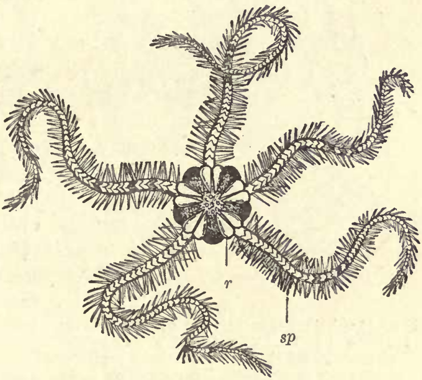

FIG. 42.—Common brittle-star (*Ophiothrix fragilis*). *r*, radial shield; *sp*, spines.

twenty times that attained by the common starfish. The arms, or rays, are very long and slender, so slender that there is no difficulty in realising that they do not, like those of the starfish, contain prolongations of the digestive organs, which here, like the reproductive organs, are confined to the disc. The tube-feet are also reduced, are no longer placed in an open ambulacral groove, are not used in locomotion, and are small and tentacle-like in appearance. Between the rays there are peculiar bursæ (*b* in Fig. 43), or pockets, which open to the exterior by deep slits placed at the sides of the rays. These are breathing organs, and are very characteristic of brittle-stars.

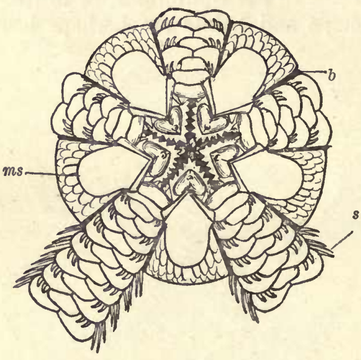

FIG. 43.—Diagrammatic view of the under surface of the disc in the sand-star (*Ophiura*). Of the five rays three are cut short close to the disc, the other two just beyond its limits. In the centre is the star-like mouth; the triangular plates which project into it are fringed by mouth-papillæ. The presence of teeth is also indicated. *b*, one of the bursal slits; *ms*, one of the mouth-shields; *s*, arm-spines.

This general survey of a brittle-star should make the main points of contrast with starfish clear, but the details of structure are difficult; we can only indicate the more important points. First, as to the rays: among the dried wreckage near high-tide mark, you will always find skeletonised brittle-stars which will show that the arms are made up of a series of segments or vertebræ, jointed together. Outside these segments there are a series of plates, one of which is placed on the dorsal surface of each segment, one on the ventral, and two at the sides. These last, the lateral, plates bear spines. The delicate tube-feet emerge at the side of the rays, and there are one or two little plates, called the tentacle scales, at the point of exit. In regard to the disc the dorsal surface is variously marked in the different species, but there are usually two distinct plates, called radial shields, at the origin of each ray. On the ventral surface we have the mouth, which has a complicated structure. The main points are indicated in Fig. 43, which is a diagram of the parts in the sand-star (*Ophiura*). The actual mouth-opening is small, for from its margin five triangular projections jut inwards, the apex of the triangles being towards the centre. These projections arise between the arms, and as they do not touch one another, the mouth-cavity consists of a small central space continued into five slits, the slits corresponding to the rays. Into these slit-like spaces the first tube-feet of each ray project, and function as tentacles. The minute structure of the triangular projections is of some importance in identifying species. Each consists of a basal plate, or mouth-shield, and two lateral plates in contact throughout the whole or part of their length. In some cases these lateral plates bear small spines at their edges, so that the mouth-clefts are fringed by spines. Such spines are called mouth-papillæ. Again, spines may be present at the apex of the triangle, such spines being called tooth-papillæ. Finally, beneath the tooth-papillæ, and within the mouth-cavity, there may be smaller spines called teeth. The madreporite in brittle-stars is on the ventral surface, and not the dorsal as in starfish, and replaces one of the mouth-shields.

The common brittle-star (*Ophiothrix fragilis*), which in most places is very common, is to be found under stones and among tangles between tide-marks. Fair-sized specimens measure three to four inches from tip to tip, but the arms are very brittle, and break off at very slight provocation. The colours are bright and variable, the rays being usually banded, and the disc of a contrasting colour. Reds, browns, and yellows are common tints, but the rays are frequently violet or grey. The arms are flattened, and the most characteristic point is the presence of long notched glassy spines borne at the sides of the arms in bunches of seven. Some other more minute points of structure may be given as follows. There are no mouth-papillæ, so that the sides of mouth-clefts are unnotched, but there are numerous tooth-papillæ and teeth. On the dorsal surface of the disc the radial shields are very conspicuous, but the rest of the disc shows much variation in the presence or absence of spines. The whole animal, indeed, shows much variation, and it is so common that it is interesting to study the variation in detail for any locality.

Almost as abundant as the common brittle-star is the daisy brittle-star, which occurs in similar localities. The differences between the two are not very easily described, though an examination of actual specimens should make them obvious enough. Perhaps the most obvious difference is in the spines, which in the "daisy" are short and stout. The arms themselves are wide and flat, less fragile, and not so long as in *Ophiothrix fragilis.* They are usually beautifully banded with alternate bars of red and white. There is no difficulty in learning to distinguish these two common brittle-stars by what may be described as mere "rule of thumb," but those who care to make their knowledge exact may welcome a brief account of the more minute peculiarities of the "daisy." Its scientific name is *Ophiopholis aculeata,* and among its notable characteristics are the fact that the upper arm plates are surrounded by small additional plates, that the disc is so covered by granules that the radial plates are rendered obscure, and that while teeth-papillæ are absent, three mouth-papillæ are present at each side of the mouth-clefts. The spines borne by the lateral arm plates are seven in number, and, as already stated, are short and stout.

Both the common and the daisy brittle-stars live fairly well in confinement, especially in the case of small specimens, and they are well worth the careful study which can be most readily bestowed on captive specimens. Like other brittle-stars, they are somewhat difficult to study and to name, both on account of the complexity of their hard parts, and of the great colour variability. As regards the question of naming your specimens, one hint may be given, though it is one the beginner is apt to resent—it is, do not forget to look at your specimens before you try to name them. Very many people who are interested in natural objects begin systematic work with British flowering plants, and are then apt to acquire the pernicious habit of naming specimens by what one may describe as a mere trick—the shape of the petals, or of the fruit, or some other single point. The educative value of species work, however, certainly in the case of animals at least, is its training in the perception of form, and one should strive to learn not merely to count or measure spines, but to perceive those real differences of form which are often so difficult to explain in words, but which constitute the true distinctions between species. The brittle-stars are especially adapted for exercises of this kind, and before you begin to study the minute details of structure, you should strive to acquire an exact knowledge of the general form. It is an interesting if somewhat humiliating experience to look at a brittle-star for a few minutes, then to cover it up and endeavour either to draw or to even merely visualise the specimen, and then compare your mental image or your sketch with the real object. Both generally leave much to be desired in the way of precision.

There are a considerable number of other brittle-stars, or sand-stars, which may occur between tide-marks, especially after storms. One which occurs there freely in the living condition, but is liable to be overlooked on account of its small size, is *Amphiura elegans.* It should be looked for under stones, and does not usually exceed one inch to one and a half inches in length. The colours are sober and inconspicuous, and the creature may be recognised by its round disc with well-marked radial shields, and the slender arms whose side plates bear three to four inconspicuous spines. There are three mouth-papillæ on either side of the mouth-clefts. After storms, or among the wreckage at most seasons of the year, the common sand-stars *Ophiura lacertosa* and *O. albida* are to be found. They can be recognised by the fact that the disc is cleft at the origin of the arms, the clefts being fringed by papillæ. In the larger, *O. lacertosa*, these papillæ are ten to twelve in number, while in the smaller, *O. albida*, they number about thirty. The arms bear only minute spines, which are so closely adpressed to the sides of the arms that they are not seen on casual view. The disc is completely covered with scales. The sand-stars occur perhaps most frequently in the skeletonised condition, high up on the shore, and are then admirable subjects for the study of the Ophiuroid skeleton (see Fig. 43).

The Ophiuroids in general offer many interesting points of contrast with the starfishes. While in the latter it is common to find that the arms exceed five in number, in the Ophiuroids this is not the case. As the name brittle-star indicates, the Ophiuroids are generally very fragile, but the somewhat rare starfish *Luidia* shows that the same fragility may occur in the Asteroids. Indeed, though our British Asteroids and Ophiuroids are sharply marked off from one another, when the groups are considered as a whole their close relation becomes obvious.

On account of the large amount of lime in the tissues, the starfishes and some of the Ophiuroids make good dry preparations, and are often most easily preserved in this way. In the case of the larger starfish it is desirable to remove some of the water from the tissues before allowing the specimens to dry. This is best accomplished by placing the animal in spirit for twenty-four hours, changing the spirit once during that time. This "dehydrating" process may be conveniently carried out in a pie-dish covered by a plate. Afterwards the starfish should be lifted out and allowed to dry slowly in air; a well-ventilated outhouse, or, in default of it, a shady window-ledge, is a good situation for the process. The dried specimens should be kept in a cabinet with camphor or some other preservative against the attacks of insects; if they become damp, or show signs of "going wrong" in any way, a repetition of the dehydrating and drying process is often effective. In the case of the brittle-stars, the prime difficulty is usually to obtain a perfect specimen either to dry or to preserve, for the animals usually break up in dying. In some cases at least specimens may be instantly killed without rupture by dropping them suddenly into boiling water, and as death is practically instantaneous, the objection of the apparent cruelty need hardly be entertained—apart from the other debated question how much a brainless animal like an Ophiuroid can really "feel." Specimens killed in this way become abnormally brittle after death, and must be handled with extreme caution.

The next set of Echinoderms is constituted by the sea-urchins, which have this advantage over the brittle-stars that they are more or less familiar to everyone. To study the general characters you should provide yourself with a good number of the empty shells, or tests, which usually ornament cottage windows near the sea, and are to be found on the beach at most seasons of the year. In addition, an attempt should be made to obtain one or two living specimens. It is not always easy to obtain the common urchin (*Echinus esculentus*) in the living condition, but the small purple-tipped urchin (*E. miliaris*) may generally be found in the Laminarian zone, and has the advantage that one may keep it alive in confinement longer than its relative, which needs a great bulk of water.

Let us examine the living specimens first. The common urchin is really an inhabitant of fairly deep water, but I have often taken single specimens at low spring tides, and where the shore slopes steeply the urchins may sometimes be seen in numbers by looking over the edge of the rocks. The colour is usually purplish pink, but I have found specimens entirely straw coloured, with beautiful purple tube-feet. The test is rounded, and in life covered by numerous long spines. In *E. miliaris*, which is very much smaller, the diameter often not exceeding that of a penny, the test is flattened, and the numerous spines are short and not of uniform size. The general tint is green, but the spines are tipped with purple. In either urchin you will notice the mouth in the middle of the under surface. It is surrounded by a membrane which is very extensile, so that the mouth can be protruded to a considerable extent, and then withdrawn. The object of this, as a living active urchin will show, is to allow of the free movement of a complicated tooth-bearing structure called Aristotle's lantern. This contains a circle of five chisel-edged teeth (see Fig. 44) which may be seen and felt in the mouth of the urchin, and are borne by an arrangement of ossicles, which permit the teeth to open and close so that the urchin can crop seaweed as effectually as a rabbit crops dandelions. Their action is greatly aided by the elastic mouth membrane, which is covered by small tube-feet which act as tentacles, and by little stalked forceps called pedicellariæ, curious structures common among the Echinoderms, and probably serving to keep the test clean.

The presence of this mouth-membrane and of Aristotle's lantern has a rather interesting effect in the case of dried specimens. If you have a fair collection of these, you will probably find among them some which present much the same appearance as the living specimens, spines, mouth-membrane, and teeth all being present as usual. In not a few cases, however, you will notice that the soft membrane shows signs of decay—either it cracks in dying, or it is attacked by sand-hoppers or some of the shore insects. The result is to set free the bulky and heavy lantern. This may then simply fall out of the empty test, and be found lying intact on the sand, or more probably its ligaments speedily decay and one finds merely the scattered ossicles and teeth among the wreckage. By the decay of the membrane the cavity of the urchin is fully exposed, and the soft parts are speedily

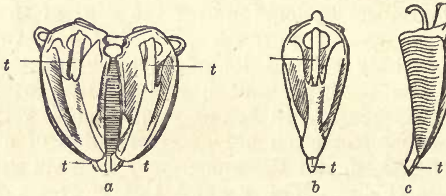

FIG. 44.—Portions of Aristotle's lantern from a sea-urchin. *a*, external view of the lantern, showing two of the five main pieces (alveoli) of which it is composed; *b*, internal view of single piece; *c*, side view; *t*, in each figure, one of the five chisel-edged teeth, which run through the alveoli and are carried by them.

eaten up, or dried up by the sun. The test then becomes very light, is rolled over and over by the waves, so that the spines are removed, and there is left the familiar empty shell with a gaping orifice beneath, and a surface covered by white knobs which show the places where the spines were formerly attached. In other cases the disintegration of the membrane is only partial, and the lantern merely falls into the cavity of the urchin. Specimens of this kind often occur with the lantern loose inside, and rattling at every movement. As the lantern is heavy, the result in this case is often to break the test in pieces, when the separated waterworn pieces appear on the shore as what children call "sailor's cheese."

After this digression we may return to our living urchin.

More obvious than mouth and teeth are usually the long slender tube-feet, which form five double bands over the test, and can be stretched out to a great length. They, indeed, give the sea-urchin a great part of its beauty, and in life are in constant movement, now extended, now contracted. By this means the sea-urchin is enabled to crawl up a perpendicular surface. The only other point which can be readily observed in the living urchin is the posterior opening of the food canal at the point opposite to the mouth. It is surrounded by small plates of lime, and, as these are readily removed, is in consequence often represented by a large hole in dried specimens.

To study the composition of the urchin's test in detail we must return to the dried specimens from which the spines have been rubbed off. As already noticed, the mouth is usually now represented only by a gaping hole, by which the lantern has been shaken out. The anus may or may not have lost its small plates, but around it will be seen ten distinct plates, which mark out as many radii on the shell. Five of these plates bear each a distinct round hole, which is the opening of the reproductive duct, but one of the five is in addition perforated by minute holes, and so constitutes the madreporite. The other five plates are smaller, and bear each an eye-spot. In a line with these five plates are the five ambulacral areas of the test, which each consist of two rows of plates perforated by the minute pores through which the tube-feet emerge. In addition these plates, which are relatively narrow, bear a few spines. Corresponding to the larger plates, and thus alternating with the ambulacral areas, are five interambulacral areas, each consisting of a double row of wide plates, bearing numerous spines. The net result is to produce in the living urchin five double rows of tube-feet, separated from each other by a somewhat wide interval thickly covered with spines. The spines have a curious ball-and-socket joint at the base, and are very freely movable. They assist in locomotion, and must also protect the test from mechanical injury. The large urchin lives freely exposed, and probably from its strong armour has little to fear from the attacks of enemies; but the little purple-tipped urchin covers itself with weed and fragments of stone and shell as though to seek protection. It is in consequence not very easily seen except by careful search, but is common enough in the Laminarian zone. The depressed shape and green and purple colour make it easily recognised. As already indicated, the common urchin only occurs somewhat sporadically between tide-marks, but it is at times thrown on shore in great numbers after gales, and is generally to be found in the dry condition on the beach. The diet of both urchins seems to vary, probably in part according to the locality; in many places both live largely on seaweed, but are not averse to mingling this with animal matter.

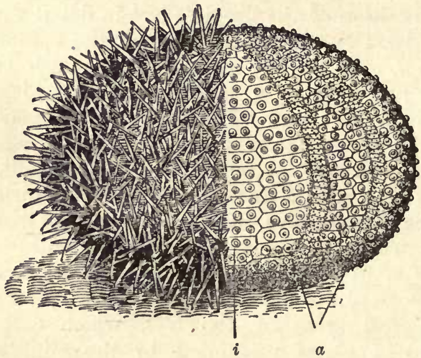

FIG. 45.—*Echinus esculentus*, common sea-urchin. The spines have been removed from half the test, to show the structure of the latter. The reference lines (*a*) inclose an ambulacral area; *i* is an inter-ambulacral area.

In both cases the internal anatomy is very interesting, and a general notion of its main outlines is easily obtained. With a strong pair of scissors make a circular incision midway between mouth and anus, and then lift off the upper segment. In it one sees the five reproductive organs, varying greatly in size according to the season of the year; in the lower we see Aristotle's lantern, which is very large relatively to the size of the animal, and is perforated by the brown alimentary canal, which, after leaving the lantern, coils about the shell, and ultimately passes upwards to end at the anus. Notice also the *stone canal*, a tube hanging vertically from the madreporite, which opens into a ring canal placed on the lantern, which again opens into five radial canals running along the inner side of the ambulacral areas. Each radial canal communicates by lateral branches with the tube-feet, and with the leaf-like *ampullæ* which lie on the inner side of the shell, and form very conspicuous objects. Perhaps, however, in the common urchin at least, you will be most struck by the apparent emptiness of the shell. It contains a large amount of watery perivisceral fluid, but even when the urchin is fully ripe seems disproportionately large relatively to the contained organs. It should be noticed that the shell is not an external structure like the coat of a crab, for its outer surface is covered by a thin layer of skin, and in development it arises as an internal skeleton. The separate plates of which it is composed go on growing during life, and in this way the whole test increases in size as the urchin grows older.

These two urchins are the commonest of our regular urchins, which are characterised by their more or less spherical shape and the regular arrangement of their tube-feet in five double rows. The majority of the internal organs, reproductive organs, nerves, ambulacral canals, etc., occur in fives; or, in other words, the symmetry is pentamerous throughout. It is otherwise with the next urchin to be considered, which has a less well developed ambulacral system, and shows a tendency to lose this five-rayed symmetry in favour of a bilateral arrangement. There are a number of such *irregular* urchins, but the commonest is perhaps *Echinocardium cordatum*, which shares with some of its allies the popular name of heart-urchin. The heart-urchins are most interesting animals, interesting both in themselves and in their contrast with the common urchins. To get *Echinocardium* in the living state one must be prepared to risk a good deal in the way of wet feet. If the enthusiasm of the naturalist rises above this objection, the next desideratum is a strong spade—not a toy, but the genuine article borrowed from the gardener—and a good low spring tide. The last is in most cases essential. Then choose a spot where the tide ebbs a long distance over sand which is shown, by abundant worm-castings and mollusc shells, to be suited to animal life, and begin work at the margin of the water. It may be well to repeat warnings already given as to the force of spring tides and the possible element of danger in shore hunting at that period. In most cases the tide rushes in over those long level flats, beloved of sanddwellers, with great rapidity, and the enthusiastic naturalist is often wise to take with him a cautious and unenthusiastic companion and a flat-bottomed boat. He will soon learn by experience whether the element of safety imparted by the presence of the boat compensates for the trouble of wading for perhaps half a mile through water too shallow for it to move or laboriously pushing it over the sandy flats. All these are mere trifles to the genuine enthusiast, and if the ground be rich, sand digging becomes a delightful and profitable amusement. You may get many curious creatures, but there is at least this satisfaction in regard to the heart-urchins, that if you find any at all you are pretty sure to find as many as you can possibly want. They occur at no great depth below the surface, in burrows of their own making, and many are at times turned up in each spadeful of sand. In life they are of a beautiful golden colour, which unfortunately speedily fades after death, and the tests are so fragile that they are often broken to pieces in the mere handling and separating from the sand.

As regards structure, notice first the silky spines, which vary much in size, and are not uniformly distributed over the surface. The test is somewhat heart-shaped, and flattened beneath, and the mouth will be found on this lower flattened surface, overhung by a lip-like process, but without any trace of a lantern. Round the mouth, and sending two diverging horns backwards, is a bare space, perforated, especially near the mouth, by pores through which a few tube-feet emerge. These are somewhat complicated in structure, having curious brush-shaped tips, and function as tentacles. Between the posterior diverging horns just mentioned is a group of interesting spines. They are stout and flattened at the ends, or spatulate. It is these which are used in excavating the burrow, their action being assisted by the other spines, which have an interesting and somewhat complicated arrangement, well worth careful study, and by the mouth process. Next turn over your specimen and study the dorsal surface. In a living specimen it is possible to make out, though less clearly than in the dry shell, that the ambulacral areas in this region show what is called a petaloid arrangement, that is, they are arranged roughly speaking in the form of a five-rayed star, and are thus something like a flower. The odd ray is to the front, and is more conspicuous than the others because it is placed in a deep groove. On the sides of this groove there are rows of spines bent inwards until they nearly meet. Place a living specimen before you with the grooved region towards you, and you will notice that the slope of the test, the position of the groove, and the arrangement of the spines, are all so adjusted as to form a definite canal, which leads from the crest of the shell straight towards the mouth with its spout-like process. Notice also that the tube-feet of the petaloid area are extensile and well developed, and so arranged as to serve to catch hold of food-particles and sweep them downwards into the groove and so to the mouth. Notice the anus near the middle of the vertical posterior region of the shell, and the peculiar rounded sub-anal area beneath it, which is liable to be mistaken for it. You will also notice, what is even more obvious in dissection, that the apertures of mouth and anus are very small indeed, showing that the animal cannot live upon particles of considerable size, as do the regular urchins.

Having made these observations on the external aspect of the living animal, you may proceed to study some of the details of anatomy. To do this you should provide yourself both with fresh specimens and with a considerable number of dried tests, in the condition in which they are to be found on every sandy beach. Dissection in the strict sense is of course impossible; but a good idea of the anatomy may be obtained by cutting open the shells with a strong pair of scissors in different directions, so as to get different views of the interior.

Let us consider first the function of nutrition. What does the heart-urchin feed upon? The first one you open will show, even if you had not previously come to conclusions on the subject from the habitat. It feeds on the minute particles contained in sand, and the alimentary canal is always filled with sand, which is swept into the mouth down the groove in the way of which we have already spoken. As sand is abundant, the urchin does not need to go and seek its food, but remains more or less passively within its burrow, and uses its tube-feet and spines in directing the food-supplies to the mouth. The food requires no mastication, and so we find that the lantern and its supports have disappeared. The position of the anus at the posterior end, instead of at the top of the shell as in *Echinus*, is probably an adaptation to life in a burrow; for as the urchin's food to a large extent must come from above, it is desirable that waste material should not be deposited where it might mingle again with the food.

What effect has this more or less sedentary life had upon the ambulacral system? In the first place it is obvious that this has at least very largely lost its locomotor functions. The feet have now no suckers; they are not, as in the common urchin, arranged so as to make locomotion in every direction possible, and indeed the shape of the test would render this impossible in any case. The tube-feet now act largely as tentacles, and also possess, as in the regular urchins, some respiratory function. We have noticed that they seem not to be continuous over the whole test, but form a petaloid area on the dorsal surface, and a similar but less well developed area about the mouth on the ventral surface. Careful examination of the interior will, however, show you that the radial canals are continuous internally, and that the upper and lower petaloid areas are connected by regions in which a few small scattered tube-feet occur. In the dry shell on the dorsal surface, to the posterior side of four pores which you will find near the upper end of the groove, you will be able with the aid of a lens to discover the madreporite, or rose-plate, which has remained in its primitive position, while the anus has moved backwards. Thus we see that the ambulacral system is constructed on the same plan in *Echinocardium* as in *Echinus;* but in the former certain of the tube-feet have, as it were, been accentuated, at the expense of others which are now only very slightly developed. It is interesting to note that the irregularity which manifests itself in the external appearance of the urchin is also apparent internally in the reproductive organs, of which there are now four only instead of five. The four pores spoken of above are the four genital pores (cf. the *five* of *Echinus*).

This description of *Echinocardium* will not be found very readily intelligible unless it is studied with the help of actual specimens, but dried specimens at least are so extraordinarily plentiful that there is no reason why this should not be done. The contrast between the regular urchins with their strong shells, uniform coating of spines, and well-developed tube-feet, and the heart-urchins with their fragile shells, on which both spines and tube-feet are distributed in so complex a fashion, and which have lost the primitive radiate symmetry, is so striking, and so intimately related to the different modes of life, that it is worth careful study. A great part of the interest attached to the Echinoderma is due to the fact that the members of the group show adaptations to many different kinds of life, while retaining those well-defined characters which make the group such a compact one. In many cases the structural adaptations to particular habitats are difficult to study, but in the heart-urchins they are fairly obvious, and intensely interesting. Between tide-marks *Echinocardium cordatum* is the only heart-urchin likely to be found in the living condition; but on the beach after storms one at times finds the purple heart-urchin (*Spatangus purpureus*). The differences between it and *Echinocardinm* are not very striking apart from colour. The most noticeable difference is perhaps the fact that in *Spatangus* certain of the spines are very long, strong, and curved—a difference probably associated with the fact that the animal lives in coarser material (coarse sand or gravel) than *Echinocardium.*

The next group of Echinoderms—the Holothurians, or sea-cucumbers—is very poorly represented on the East Coast, at any rate in shallow water, though, indeed, in any case the majority occur beyond tide-marks. For the sake of completeness we may describe a typical form, such as *Cucumaria lactea*, which does occur between tide-marks occasionally. It is a little creature, about an inch long, with a cylindrical body, and a tough skin of white or brown colour. The form is strikingly different from that of other Echinoderms, for it is characteristic of the Holothurians that their radial symmetry is not obvious, most of them being of worm-like form, and showing more or less distinct bilateral symmetry. If you obtain *Cucumaria* in the living active condition, you will see it protrude at one end of the body a beautiful crown of ten branched tentacles (*te* in Fig. 46). At the other end of the body is the anus, and between these two extremities there occur five zigzag rows of tube-feet (*tf* in Fig. 46). These are very different from the long, delicate tubes of a sea-urchin, for they are short, stiff, and can only be very imperfectly retracted. The skeleton, as in all Holothurians, is represented only by deposits of lime in the skin, which are not continuous, and are not at all conspicuous. The internal anatomy we need not consider, but may only remark in passing that most Holothurians have a distressing habit of throwing out portions of their internal organs when attacked or alarmed. In consequence one only rarely gets an intact specimen for dissection; even those which seem uninjured will often be found when opened to have lost some of the viscera.

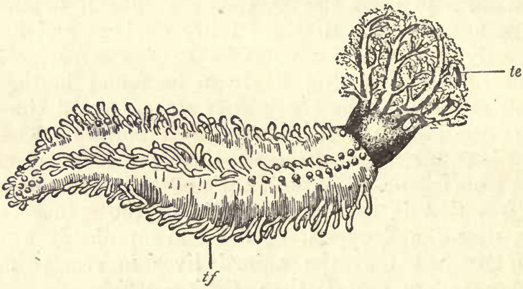

FIG. 46.—Sea-cucumber (*Cucumaria planci*). After Bell. *tf*, one of the five rows of tube-feet; *te*, tentacles surrounding the mouth.

There is one other Holothurian which occurs not uncommonly all round our coasts, though it is not often seen. If, however, you make that low-tide excursion to a sandy beach which has been recommended as the only way of getting *Echinocardium* in the living condition, you will probably find among your spoil pink worm-like creatures, which you are not unlikely to describe either as "worms," or as burrowing sea-anemones. They are slender, translucent creatures with an anterior crown of tentacles, and are usually about three inches in length. If you examine the surface of the body with a lens, and also pass your finger over it, you will notice one of the most curious characters of *Synapta*, as the little creature is called. This is the presence in the skin of little anchors of lime, whose flukes project from the surface and cling to the hand, as under natural conditions they do to the sand. This Holothurian, then, is literally and not metaphorically anchored to the sand, the anchors being numerous and scattered all over the body. If you examine a fragment of the skin under a strong lens or a low power of the microscope, you will see that each anchor is connected with a little plate perforated by seven or nine holes, and that it can move on this plate as on an axis. Plates and anchors together represent the limy deposits of *Cucumaria*, and so the limy skeleton of other Echinoderms, and are exceedingly characteristic of *Synapta.* After having once been seen they can hardly be mistaken for anything else. I once knew a learned professor who was a great admirer of these anchors, and used to bring them out with the utmost regularity whenever he presided over a zoology examination. Both they and their owner are a little out of the way of ordinary zoology students' observations, so the candidates came to grief time after time through their wild shots on the subject, until the professor was ill-advised enough to remark in a public address on the ignorance of *Synapta* which prevailed among zoological students. After that all institutions which sent up candidates to the public examinations purchased a slide displaying the anchors, and so succeeded in passing their students without the trouble of going to dig for *Synapta*, or studying its structure.

Associated probably with the burrowing habit of *Synapta*, we have the interesting fact that the tube-feet are absent from the body, and are represented only by the crown of tentacles at the anterior end. In *Cucumaria* the tentacles are also modified tube-feet, and these are the only ones which can be described as well developed. In *Synapta* the tentacles are the only representatives of tube-feet present at all. The statement that in *Cucumaria* and *Synapta*, as in Holothurians in general, the tentacles are modified tube-feet is not a mere assertion, but is justified by the relation of these tentacles to the ambulacral system, a relation easily studied in the larger Holothuria by dissection.

The only species of *Synapta* usually to be found between tide-marks is *S. inhærens*, recognised by its twelve tentacles, each with six or seven finger-like processes at either side, and by the fact that the edges of the holes of the anchor plates are serrated. As is to be expected from the habitat, it lives on the organic particles contained in sand, and the alimentary canal with its contained sand can be seen shining through the transparent body-wall. As in *Cucumaria*, the tentacles can be completely retracted, and the animal is then very worm-like in appearance.

This concludes the consideration of our common littoral Echinoderms. The forms mentioned should give the student a general idea of the main points of structure, and should serve to indicate the general interest of the group. Our common littoral forms are adapted to very various conditions of life, and while retaining certain common peculiarities of structure, present in a most interesting way what are known as adaptive characters. One very interesting point in regard to the group is, that the development is usually very indirect, the larvæ being quite unlike the adult, and adapted for very different conditions. The larvæ of our common shore species are to be sought in the tow-net near the surface of the sea, and are often very quaint in form. The study of the development is beyond our scope, but this chapter would be incomplete if it did not mention the fact that not only are larvæ and adults very unlike one another, but that the former are converted into the latter by a remarkable process of metamorphosis. Further, on account of their marine habit, and the abundance of lime contained in the tissues, the Echinoderms are abundantly represented as fossils, and their geological history is in consequence better known than that of most animals.

KEY FOR THE IDENTIFICATION OF THE SPECIES DESCRIBED IN THIS CHAPTER.

ECHINODERMA.

(1) **The Asteroids, or Starfishes.** Body star-shaped, with stout arms containing prolongations of the digestive and reproductive organs, and open ambulacral grooves.

Rays five, rarely six . .	Tube-feet in four rows, skeleton reticulate, its small plates bearing simple spines. Pedicellariæ present .	*Asterias* . .	Spines small, numerous, with one row down centre of arms —*A. rubens.* Spines large, not very numerous, arranged in three to five rows—*A. glacialis.*
	Tube-feet in two rows, skeleton reticulate, meshes bearing clusters of small spines. No pedicellariæ . .	*Henricia* . .	Ambulacral groove narrow, fringed by dense rows of spines —*H. sanguinolenta.*
Rays more than five . .	Dorsal spines brush-like, numerous, ambulacral grooves fringed by comb-like spines .	*Solaster* . .	Rays 11 – 14, colour red or purplish red, dorsal spines in tufts—*S. papposus.* Rays 9–11, colour usually purple, dorsal spines much crowded —*S. endeca.*

(2) **The Ophiuroids, or Brittle-Stars.** Body star-shaped, arms long and slender without prolongations of the digestive or reproductive organs; no distinct ambulacral groove.

Tooth-papillæ (see p. 131) present. .	No mouth-papillæ, arm spines notched, disc with spines and distinct radials . .	*Ophiothrix* .	Arms fragile and long, spines long and glassy —*O. fragilis.*

The Ophiuroids, or Brittle-Stars.—*continued.*

- No tooth-papillæ, mouth-papillæ present, spines smooth
  - Arms inserted on ventral surface; few mouth-papillæ . .
    - Spines on arms stout, not long, extra plates on arms, which are wide and flat — *Ophiopholis* . .
      - Three mouth-papillæ, seven spines at sides of arms, radials indistinct — *O. aculeata.*
    - Spines short and small, arms long, disc small with distinct radials — *Amphiura* . .
      - Three mouth-papillæ, three or four fine spines at sides of arms —*A. elegans.*
  - Arms inserted on disc, numerous mouth-papillæ .
    - Arm notches spinose, bursal slits extend to edge of disc—*Ophiura.*
      - Arm notches with more than 25 spines—*O. ciliaris.*
      - Arm notches with less than 20 spines—*O. albida.*

(3) **The Echinoids, or Sea-Urchins.** Body more or less rounded, covered by spines, test composed of plates arranged in regular rows.

- Body spherical, anus opposite mouth, five regular double rows of ambulacral plates, Aristotle's lantern present . . .
  - *Echinus* . . .
    - Test well rounded, spines pinkish or white — *E. esculentus.*
    - Test depressed, spines purple-tipped — *E. miliaris.*
- Body heart-shaped, anus posterior, ambulacral areas petaloid, no lantern .
  - Spines, and therefore tubercles, nearly equal —*Echinocardium* .
    - Colour golden when fresh, anterior tube-feet in a groove—*E. cordatum.*
  - Some spines, and therefore some tubercles, larger than rest—*Spatangus* . .
    - Colour purple — *S. purpureus.*

(4) **The Holothurians, or Sea-Cucumbers.** Body more or less elongated, without well-developed skeleton. Mouth with a fringe of tentacles.

- Tube-feet present .
  - Tentacles ten, much branched—*Cucumaria* . .
    - Tube-feet in five zigzag rows, not retractile—*C. lactea.*
- Tube-feet absent .
  - Tentacles with simple lateral branches or digits, anchors and anchor-plates present —*Synapta* . . .
    - Tentacles twelve, with six or seven digits at each side—*S. inhærens.*

NOTE ON DISTRIBUTION.

Generally speaking, the North Sea is poor in Echinoderms as compared with other parts of our area, but this is to some extent compensated for by the great abundance of certain common species on its shores. Thus, the common sun-star, *Henricia sanguinolenta*, and the common starfish (*Asterias rubens*) are probably commoner between tide-marks on the North-east Coast than on the South and West. On parts of the South and West Coasts the spiny starfish (*Asterias glacialis*) is to be found not uncommonly between tide-marks. The brittle-stars mentioned are common everywhere, but on the South the handsome yellow *Ophiocoma nigra* may also be expected between tide-marks. In regard to the sea-urchins, those mentioned in the text are widely distributed, but so far as my experience goes, *Echinus miliaris* reaches a much larger size between tide-marks on the West Coast than on the East. On the South and West sea-cucumbers are much more likely to be found between tide-marks than on the East. In addition to *Cucumaria lactea*, other species, such as *C. pentactes*, occur there.

CHAPTER VIII.

THE DECAPOD CRUSTACEA.

General characters of Crustacea—Structure of prawn, lobster, and crab—Classification of Decapod Crustacea—Swimming and creeping forms—Common British shrimps and prawns.

IN this chapter we have to consider one of the most interesting classes in the animal kingdom, interesting alike on account of the beauty of form and colour, of the structure and the habits. The class Crustacea is a very large one, and embraces a great variety of animals adapted for many different habitats and modes of life. Like the insects on land, the Crustacea seem to display every possible modification of parts; if they are less popular than insects it is certainly not because they display fewer points of interest or less beauty.

They resemble insects in being clothed in an envelope of chitin, which invests the whole body, and is inturned to line part of the alimentary canal and to form the tendons of the muscles. This chitinous coat gives great definiteness of form—the Crustacea never exhibit the variability of shape which often makes the study of soft-skinned animals so difficult; it has also such an intimate connection with the internal organs that the external appearance may be used as a test of affinity. In this respect the Crustacea, or indeed the Arthropoda in general, differ markedly from Molluscs. The shell of the latter has no very intimate connection with the internal organs, it in itself yields little information as to the anatomy of the contained animal. In consequence, the structure and affinities of Molluscs can be made out by dissection alone, and dissection, moreover, which is often tedious and difficult even for trained fingers.

On the other hand, the structure of the external parts of a Crustacean in the general case determines the systematic position of the animal, and the examination of such external parts requires more care than anatomical skill in the strict sense. The Crustacea are therefore *par excellence* the class for the novice, the one above all others in which he can hope to walk by sight and not by faith.

In studying the Crustacea it is convenient to begin with the higher forms, which are usually of such size as to make observation easy. To acquire a general knowledge of the structure, we may compare three common forms—a prawn, a lobster, and a crab. The common prawn (*Palæmon serratus*), a beautiful little creature about four inches long, is not likely to be found on the East Coast, but a smaller species (*P. squilla*) is not uncommon in rock pools, and is large enough for our purpose. The hump-backed Esop prawn (*Pandalus annulicornis*) may also be found far out on the rocks; while, failing all three, the common shrimp may be substituted. As to the second specimen, the lobsters really lie somewhat outside our province, but the Norway lobster (*Nephrops norvegicus*) can be purchased very cheaply at a fishmonger's, and is admirably adapted for the study of many Crustacean characters. Those who do not find it available will probably be able to obtain the fresh-water crayfish, or that somewhat costly luxury the true lobster. Add to your specimens the common shore crab or the edible crab, and you are prepared for the study of the characters of the Crustacea.

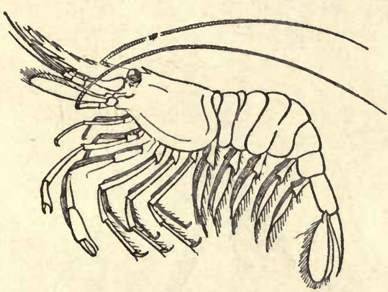

FIG. 47.—A common prawn (*Palæmon squilla*).

Place your three specimens—prawn or shrimp, lobster or crayfish, and crab—side by side, and note first their common characters. All three can be divided into two similar parts by a line down the middle of the body—that is, all are bilaterally symmetrical. All are invested with a firm cuticle of chitin, are furnished with jointed hollow limbs, and in each case the body consists of a series of similar parts or segments, least obvious in the crab. Because of these characters all are Arthropods. Further, we include them in the class Crustacea because all have two pairs of feelers (antennæ), a shell containing carbonate of lime, and all breathe by gills. The last-named structures may be readily seen in prawn and lobster by gently raising the

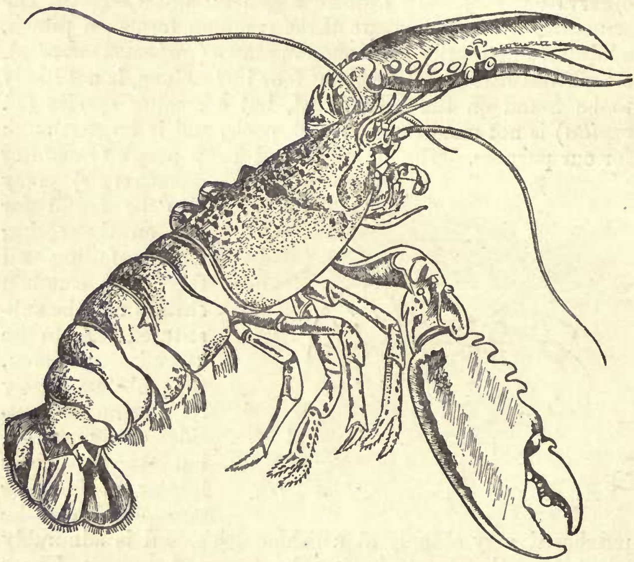

Fig. 48.—Common lobster (*Homarus vulgaris*).

large flaps at the sides of the body in the anterior region. Beneath these lie delicate structures, shaped like bottle-brushes, and closely connected with the limbs. In the crab the gills are so well protected by the shell as not to be seen without dissection.

Looking now at our specimens in somewhat greater detail we see that the prawn and lobster or crayfish resemble one another in that in both the body consists of an anterior, not obviously segmented region, covered by a shield, and a tail made up of a succession of similar parts. The anterior region we call the cephalothorax—for it is made of head and thorax united—the posterior, the abdomen or tail. The cephalothorax, or united head and body, contains the greater part of the organs of the body; the tail is mainly filled up by powerful muscles (flesh), and in both prawn and lobster serves as an organ of locomotion. The crab, on the other hand, differs markedly from the other two in that it appears to have no tail. Turn your crab over on its back, however, and you will have no difficulty in seeing that it has really a

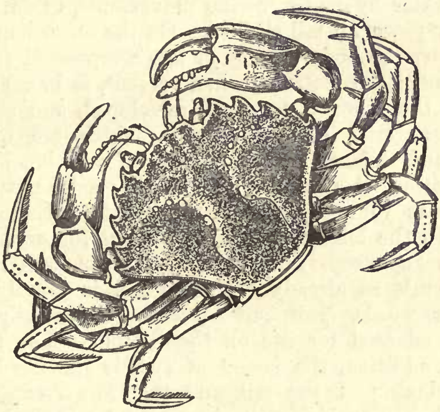

FIG. 49.—Shore crab (*Carcinus mœnas*).

true tail, reduced in size, useless for locomotion, without muscles, and habitually carried reflexed on the body, but a tail none the less. The body of the crab, no less than that of prawn or lobster, consists of cephalothorax and abdomen, but the proportions of the two parts differ markedly. In consequence of this marked difference the order of Crustacea to which the three forms belong (Decapoda, or forms with ten legs) is often divided into long-tailed forms, such as shrimp, prawn, and lobster, and short-tailed forms, such as crabs.

Although there is considerable resemblance between prawn and lobster as contrasted with crab, a little more detailed observation will convince you that in some respects the crab and lobster resemble one another closely and differ from the prawn. Thus the body of the latter is laterally compressed; its dorsal shield is prolonged forward into a great beak, or rostrum, which is narrow from side to side; its ten legs are placed very near the mid-ventral line, and are very slender as compared with the weight of the body; its powerful tail is furnished not only with tail fins, but bears also five other pairs of well-developed oar-like *swimmerets*. clearly shown in the figure. In brief, it is essentially a swimming animal, capable of supporting itself in mid-water by gentle rowing movements, or darting backwards by powerful tail strokes. On the other hand, in crab and lobster the body is more or less compressed from above downwards; the rostrum, when present, is broad from side to side; the legs are very well developed, and are divided into an anterior pair of forceps, which are weapons of offence and defence, and four pairs of walking legs, which are not attached at the middle of the body, but at such a position as to most readily support the weight of the body. In the lobster the tail is a powerful organ, but the swimmerets, except the last one, are not well developed. In the crab, as already seen, the tail is greatly reduced. In other words, crab and lobster are typically creeping animals, adapted for life on the bottom. The lobster retains, in addition, the power of swiftly darting backwards by the flexing of the tail, and therefore retains also the long feelers, movable exposed eyes, and some other characters in common with the prawn; but the crab can only crawl, and is adapted throughout for life among stones and weed.

If you have observed these points in your intact specimens, then the next thing to be done is to take them to pieces. Living specimens are best killed by dropping them into very hot water for a few minutes. Of the three, the Norway lobster, or crayfish, is the easiest to dissect. For full details as to method, reference should be made to one of the ordinary biological text-books, such as Marshall and Hurst's *Practical Zoology*, or Thomson's *Outlines of Zoology;* here we can only consider those points which are of importance in our systematic survey.

Notice, first, that the shield, or carapace, is prolonged forward between the eyes into the strong spiny beak, that in its anterior region it has a strongly marked groove which runs forwards to end near the outer side of the second pair of antennæ, or feelers, and that it is prolonged at either side into the large gill-covers which protect the lateral gills. Besides the distinct groove, other dorsal markings divide the carapace more or less distinctly into regions. Of these, the most distinct are the *gastric* region immediately behind the rostrum, with a *hepatic* region at either side. Behind it is the *cardiac* region, which has at either side the large *branchial* regions. The regions are named after the organs which lie beneath them, and are indicated in the figure of the crab. The tail differs considerably from the anterior part of the body, for it consists of six similar rings, each carrying a pair of appendages, and an end piece, or *telson*, without appendages. Each ring consists of an arched dorsal portion, two projecting side flaps, a socket for the limb, and a ventral bar with a spine in the middle. Typically in the Crustacea the whole body should consist of such rings, but in the three specimens chosen the anterior thirteen rings are fused together, and are overlapped by the great shield, which has grown backwards from the anterior segments. The function of this shield, as already seen, is to protect the viscera and gills.

Perhaps at this point it may be well to interpolate a note on terminology. To the beginner it may seem that the greatest drawback to the study of Natural History is the number of technical terms used to describe even the simplest animal, and that the number of these terms has been needlessly multiplied. This last is perhaps a point which might be debated, but we may notice that the use of technical terms is justified on two grounds. First, they have perfectly definite meanings, which cannot be said of the majority of their Anglo-Saxon equivalents; and, second, they express concisely, and in a word, a meaning which it would require an English phrase to make clear. The term Decapod Crustacea, for example, gives a naturalist a perfectly clear idea of a group of animals which would in English be inadequately described as "hard-coated animals with ten legs." Although, therefore, an effort has been made to keep down the number of technical terms in this book so far as possible, they have been used whenever clearness and conciseness would be sacrificed by their absence. Among the Crustacea especially, a certain number of such terms seem absolutely necessary, if the relation between the different forms is to be made clear.

Returning to the study of the crayfish, it is obvious that if the cephalothorax contains thirteen united segments, and the tail six free ones, and each of these segments bears a pair of appendages, then there must be nineteen pairs of appendages, apart from the tail-piece, or telson. These nineteen pairs of appendages are most easily studied by beginning at the posterior end, removing the appendages of one side successively, and laying them out in order.

In the following list they are for convenience described from before backwards:—

(1) First antennæ, or antennules, consisting each of a stalk, or *peduncle*, and two short whips, or *flagella*.

(2) Second antennæ, or antennæ proper, consisting each of a peduncle, bearing an outer broad flat scale, or *squame*, and a long inner flagellum.

(3) The mandibles, hard, toothed plates, close to the mouth.

(4) First pair of *maxillæ*, or jaws, small, delicate, and probably functionless.

(5) Second pair of maxillæ, also very delicate, but furnished with a plate—the baler—of much importance in respiration.

(6, 7, 8) Three pairs of foot-jaws, or *maxillipedes*, consisting of a basal piece and an inner and an outer branch. The inner branch, especially in the third maxillipede, is more or less leg-like (see *b* in Fig. 50).

(9) The great forceps, or chelipedes.

(10, 11, 12, 13) The four pairs of walking legs, all with seven joints. (It is because of the presence of these five pairs of "legs" (appendages 9–13) that the three types are included in the order Decapoda.)

(14, 15, 16, 17, 18) The small swimmerets, typically consisting of a basal piece and an outer and an inner branch, but the first two pairs are more or less modified in the male.

(19) The last pair of swimmerets, or *uropods*, large and powerful, with the telson constituting the tail-fan.

Besides these nineteen pairs of appendages, we have the large, compound, stalked eyes, which consist of a number of eye-elements compacted together.

As the thoracic appendages are removed, it will be found that some of the gills come away with them. Break away the gill-cover at the other side of the specimen you are dissecting, and you will see that the gills lie in a chamber opening freely to the surrounding water in front and behind. In order that the lobster may breathe, it is necessary that these gills be continually washed with fresh water. When the lobster is swimming, or in a typical swimming Crustacean like the prawn, this is accomplished by the movement of the whole animal through the water; but in a state of rest the lobster would asphyxiate were it not that its second maxillæ are in constant movement, and by baling the water out in front cause a constant current to pass in at the posterior end of the gill-cover. This is readily seen in a living Crustacean by suspending fine particles in the water in which it is living, and is a point of great importance. It is an advantage to the Crustacean to have its delicate breathing organs protected by a gill-cover, but this advantage brings with it the necessity for a mechanical means for constantly renewing the water beneath the cover. In crabs the protection of the gills is more efficiently provided for than even in prawn and lobster, and they are less actively motile animals than either. The result is that the renewal of the water under the gill-cover of the crab has to be provided for by active means, and many of the striking peculiarities of the crab are associated with this fact.

If you can obtain more than one specimen of *Nephrops*, it is a good plan to dissect one, and then use the experience gained to make a permanent preparation of another, laying out the parts in order on a sheet of card or glass. The flesh should be removed from the larger appendages, the rings of the abdomen separated and cleaned, and the great shield removed entire. During the process of preparation you will find two skeletal parts which we have not yet noticed—the so-called internal skeleton of the thorax, and the gizzard. The former is a very complex structure, formed in part by the fusion of the ventral and lateral elements of the thoracic segments, and in part by additional structures. It will be recollected that the cephalothorax or anterior region is as truly formed of segments as the abdomen, but that it is overlapped by the great shield which has developed from the anterior segments. In consequence, the skeleton of the overlapped segments has in part disappeared, in part developed into the apparently internal skeleton which protects and covers the nerve cord.

The gizzard is that part called by cooks "the lady in the lobster," and it contains firm limy bars bearing teeth which clash against one another and grind the food. It should be washed out and split open to see the teeth and bars.

When all the parts of the crayfish are cleaned and laid out in this way, they can be left to dry, and the whole will be found exceedingly useful for reference afterwards.

The next point is to compare the crayfish in detail with the prawn. We have already noticed the similarity in broad outline, but there are some interesting differences in detail. Notice in the prawn the laterally compressed beak, as compared with the flattened one of *Nephrops;* this is of course associated with that difference in the shape of the body which we have already noticed. The most striking differences are, however, to be found in the nature of the appendages. The filaments of the antennules are long, and, if the prawn be a *Palæmon*, each antennule will bear three instead of the two of *Nephrops.* This is a point of minor importance, however, as compared with the structure of the antennæ. They will be found to have a relatively enormous squame, or scale, as contrasted with the small one of *Nephrops;* while the crab, again, has no trace of antennal scale at all. The scale is a heritage from far-off swimming ancestors, and diminishes in size as the swimming power diminishes.

The maxillipedes of the prawn (*Palæmon*) resemble generally those of the crayfish, but the walking legs differ markedly, as already noticed. They are very long and slender, the first pair especially being so slender as to resemble feelers rather than legs; they are habitually carried folded upon themselves, and end in minute forceps. The next pair are larger and stronger and also end in forceps, and the last three pairs are simple, ending in sharp claws. The legs will be found to differ a little in the different kinds of prawns, but are always very different from those of lobster or crayfish.

The tail is remarkable for the great development of the five anterior pairs of swimmerets, as compared with those of *Nephrops*. Most of the above points should be readily made out from the accompanying figure.

If from the prawn we turn to the crab, we find well-marked differences from both prawn and lobster. It is only possible to point out some of these differences. The carapace has been, as it were, strongly flattened out, and in the process the rostrum has disappeared, and the relative position of eyes, antennæ, and antennules altered enormously. Prawn and lobster swim rapidly, and as they swim their long feelers, their freely movable eyes, make them fully aware of their surroundings, while their vigorous tail strokes remove them instantly from the dangers of which those keen sense-organs give them notice. But the crab only moves slowly; it only requires to be made aware of its immediate surroundings; it is often content to offer a passive resistance to foes. Therefore its antennæ are shorter, less prominent, and capable of more or less complete retraction; the eyes are sunk in orbits which protect them from harm even if they also limit the field of vision. The gills are more efficiently protected, and the parts about the mouth are much modified. Again, while in prawn and lobster more than one pair of legs bears terminal forceps, in the crab it is only the first pair which is thus modified; the others are simply pointed, and used for locomotion only.

Let us look now at these points in a little more detail. The carapace, or shield, of the crab is in essence similar to that of prawn and lobster, and shows a similar division into regions, but, besides being flattened and expanded laterally, it is inturned at the anterior and lateral margins. This is readily seen, and the change may be expressed in a rough metaphor by saying that a crab's shield is like that of a lobster which has been crushed flat. As a result in part of this crushing, we find that the lateral area which in the lobster or crayfish forms the *vertical* gill-cover has here become *horizontal*, and is separated from the remainder of the shield by a distinct movable suture The inturning of the carapace in the frontal region has, as it were, carried in with it the insertion of the antennules, so that we no longer find these on the dorsal surface, but placed in little pits beneath the margin of the shield. They are very short, consist of one filament only, and are carried doubled up when not in use. The eyes, instead of lying above the antennules, are shifted outwards, and lie in somewhat elongated sockets, or orbits, into which they can be completely retracted. The very short antennae, without trace of scale, are squeezed in between orbits and antennules. Their peduncles are very short, the basal joints being lost in a triangular plate which lies in front of the mouth.

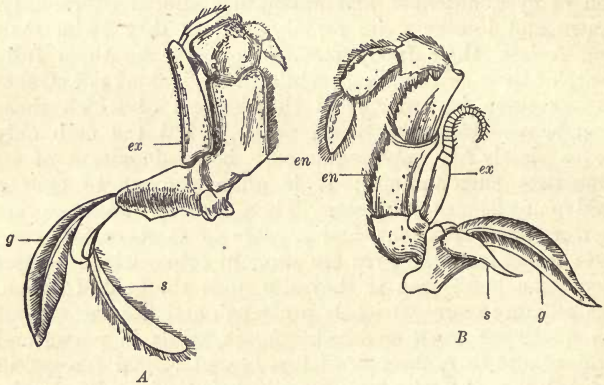

FIG. 50.—Maxillipedes, or foot-jaws, of edible crab (*A*) and lobster (*B*). In each figure, *g* is the gill, *s* the gill separator, *ex* the outer branch, *en* the inner branch.

On the minor peculiarities of the mouth parts we need not dwell. It is sufficient to note that they are more crowded and overlap one another more completely than the similar parts in the lobster. The point which is especially worth notice, however, is the character of the third maxillipedes. As is seen in the figure, in the lobster these are distinctly leg-like, but differ from the walking legs proper in that they have a slender outer branch in addition to and arising from the same base as the leg-like inner branch. The third maxillipede of the crab has in essence the same structure, but its inner branch, instead of being leg-like, is converted into a flattened plate, covering over all the anterior appendages, and closing the anterior opening of the gill-chamber. In *Mysis*, a simpler Crustacean than any of those yet considered, all the eight thoracic appendages are similar, all consist of a basal piece with a leg-like inner branch and a slender outer branch. In prawn and lobster the anterior three only retain this "biramose," or two-branched structure, but they otherwise generally resemble the walking legs proper, this being especially true of the third. In the crab these three maxillipedes are fundamentally modified to subserve functions connected with respiration and mastication, and the structural gap between them and the true legs attains its maximum. It is facts of this kind which induce morphologists to regard the crab as more specialised than the lobster, though it has lost some of the powers which the latter possesses.

The legs of the crab will be found to display many interesting peculiarities. The first pair are always the largest, and constitute the main weapons of offence and defence. Their shape and markings are often characteristic of the species, and in many cases they fit in repose very closely to the margin of the carapace, a point we shall consider later. Near their base is the slit through which water enters the gill-chamber; a carapace which has been removed with sufficient care not to damage the movable gill-cover will show a notch at this point. The remaining four pairs of legs never bear forceps, and differ markedly in the shore crab and the edible crab. They always form the organs of locomotion, and are inserted laterally so as to form an efficient support for the body. The last pair arises somewhat dorsally. An interesting point about them is that all are made of six pieces only. In the lobster the chelipeds, or great claws, have six joints, the other legs seven. A careful comparison will show that this is due to the fact that in the great claws segments two and three, counting from the base, are fused together, the line of junction being clearly marked. When a lobster throws off its great claws, as it often does when frightened or molested, separation takes place at this junction line. A lobster only possesses the power of throwing off its great claws, and not the other legs; but in a crab where all the legs display this peculiar modification, any one of them may be thrown off. Separation always takes place at the one point, and the fusion of segments is to be regarded as a special adaptation to facilitate this *autotomy* or self-mutilation. In this respect also, therefore, the crab shows an increase of specialisation as compared with the lobster.

Turning now to the ventral surface of our crab we find that, as already noticed, the rudimentary abdomen is flexed, and lies along the ventral surface of the thorax. But it is much narrower than the thorax, and the lateral insertion of the legs exposes the ventral surface of the latter much more fully than in prawn or lobster; so we find in the first place that this ventral surface is in the crab very firm and hard—completely calcified. Bend the abdomen gently backwards, and you will see that the thorax has a deep ventral groove in which the abdomen habitually lies. The abdomen itself bears rudiments of appendages, but these are much reduced. Let us recall for a moment the abdominal appendages of prawn and lobster or crayfish. In the prawn there are six pairs of functional swimmerets, the last pair being much the largest. In the lobster the first pair is rudimentary in the female, and curiously modified in the male; the next four pairs are small and of little use in swimming, though in the female they carry the eggs; the last pair is large, and forms with the telson the powerful tail fan. In the crab, with the reduction of the abdomen, we have the total suppression of this tail fan, and the development of the others varies in the two sexes. In the male the two anterior pairs only are present, and are much modified; in the female four pairs are present; they are long and delicate, and furnished with numerous hairs. As in the lobster they are used for carrying the eggs. The number of segments in the abdomen of crabs tends to be reduced, more especially in the males.

We have thus briefly revised the main points of external structure in three types of Decapods, and may look for a little at the order in general. We have already noticed the striking resemblances between prawn and lobster which have led naturalists to classify them together as Macrura, or long-tails, in contradistinction to the short-tailed crabs, and have also mentioned that other possible division which places the prawn as a typically swimming animal, in opposition to the creeping crab and lobster. Accepting this last division, we find that the swimming Decapods, or *Natantia*, have the following characteristics in common: The body is always more or less compressed, as is also the rostrum. The abdomen is well developed, its first segment is not markedly smaller than the rest, but the second is usually very well developed. The antennæ have a five-jointed peduncle and a large scale. The thoracic limbs are slender, are all seven-jointed, and only in rare cases is the first better developed than the others. Usually more than one pair are furnished with chelæ, and the penultimate segment is attached to the antepenultimate by one fixed point or fulcrum only, so that it swings less easily than in the Reptant Decapods where there are two fixed points. The abdominal appendages are used for swimming. When the female carries the eggs about with her, which does not invariably happen, the second pair of swimmerets have a brood-lamella attached to them; this is seen in the common prawn (*Palæmon*). Examples of Natant Decapods are shrimps and prawns, of which there are many kinds. Our British forms are all relatively small, but some tropical prawns attain a length of nearly a foot. Most are more or less social, and are found swimming in shoals.

With these swimming Crustacea are contrasted the *Reptantia,* which have the following characters: The body is depressed, with a flattened rostrum, or without a rostrum. The abdomen is sometimes well developed and sometimes reduced, but its first segment is always distinctly smaller than the others. The peduncle of the antennæ is reduced, and the scale is sometimes absent. The thoracic limbs are strongly developed, are usually six-jointed, and the first is the largest. The penultimate joint is attached to the antepenultimate by two fulcra, or fixed points. The swimmerets are always more or less reduced, and in the female always carry the eggs.

It might be supposed that the Reptant Crustacea could be sharply divided into two sets—the crabs and lobsters—but we shall find that there are many transitional forms. Our British forms are typically larger than shrimps and prawns, do not usually occur in shoals, and are often littoral. They show much greater diversity of structure and habit than the prawns, and have apparently been subjected to a much keener process of selection. There are in consequence few groups of marine animals which illustrate the problems of evolution more clearly, or afford more fascinating objects for study. One may read many books on the Doctrine of Descent, and yet remain untouched by the charm of the theory, but few persons can, I imagine, toil over the structure and affinities of these Crustacea without suddenly becoming conscious of the grandeur of the generalisation, of its power of unifying what previously seemed insignificant details.

We shall now proceed to consider successively typical British representatives of the Decapoda.

The members of the sub-order Natantia all fall into the family Carididæ which has the characters of the sub-order.

A large number of genera are included in this family, but it is only possible for us to consider a few of them. We may repeat, however, that the great interest of these forms is that on the one hand they show close relationship to the next lower order of Crustacea, the Schizopoda, and on the other they markedly resemble the Reptant Decapods. This is especially true of the lowest forms, notably the curious shrimp *Peneus*, which seems to stand half-way between the Schizopods and the crayfish and lobster. This shrimp is, however, a Mediterranean form, and only occurs very rarely in the South-west of Britain.

It is worth while to notice here that there are a number of interesting Crustacea which are rare in Britain, and are confined to the South and West. Such forms are almost always Mediterranean species, and we may say generally that our littoral fauna is of two types, the Mediterranean type, which predominates on the South and West, and the Northern, or Scandinavian type, which predominates on the North and East. In addition, on the West we find certain peculiar animals which are not truly members of our fauna, but are brought, more or less passively, by the Gulf Stream. Animals which occur all round our coasts may generally be assumed to be common to the Scandinavian and Mediterranean faunas, while our East Coast rarities are Scandinavian types. The differences between East and West are often exceedingly striking, and cannot fail, for example, to astonish anyone passing from the Firth of Forth to the Firth of Clyde. One must suppose that in many cases it is the warm currents which wash our western shores which have carried the Mediterranean animals northwards, but the fact that the shore on the West Coast is generally more rocky than the East, and is often fringed by deeper water, has no doubt also much influence.

As *Peneus* is too rare to be described here, the first of the Carididæ which we shall describe is the common prawn (*Palæmon serratus*). This is the largest of our prawns, and on certain parts of the coast, together with the much smaller *P. squilla*, is the object of an important fishery. Both turn bright red when boiled, and are so popularly distinguished from the common shrimp, which merely turns a brownish pink. A species of *Palæmon* may be instantly recognised by the fact that each antennule bears three feelers, of which two at least are very long, and by the fact that both the first two pairs of feet are furnished with distinct forceps, the second being much larger than the first. As other characters we may note the large rostrum, which is strongly toothed, and projects far forward between the eyes; the position of the antennæ, which are inserted beneath, and only slightly to the outer side of the antennules; and the other characters incidentally noticed in the description of the prawn.

As to the species, on the East Coast *P. serratus* is not very likely to be seen except in a fishmonger's, but on certain parts of the coast young forms are not infrequent between tide-marks. The colour is greyish, with spots and markings of brown and red. The rostrum is very long, longer than the large scale of the antennæ, and turns up at the point, forming a cruel-looking weapon. It has eight or nine teeth above, placed near the base, and five or six beneath. The filaments of the antennæ, and two of those of the antennules, are very long, so that the trailing threads are very conspicuous objects. The strong abdomen, with its well-developed appendages, has already been noticed.

The other common species of prawn (*P. squilla*, Fig. 47) is also typically an inhabitant of deep water, but it occurs not infrequently in rock pools, especially at low tides. Such specimens are usually females carrying eggs. The colour is greyish white with touches of brighter colour. The differences from the preceding species are not very well marked, especially if only small specimens of *P. serratus* are available; but it will be noticed that in the present form the rostrum is nearly straight, and has seven or eight teeth above, and only three beneath. The rostrum is also relatively shorter, and it does not usually exceed the length of the antennal scale. The whole prawn does not exceed two inches in length. Either of these prawns will repay careful study, for which their relatively large size peculiarly fits them. There are some other British species of *Palæmon*, but these are rare, and need not be considered here.

The next form to be considered is the Esop prawn, or shrimp (*Pandalus annulicornis*), which, like the true prawns, is typically an inhabitant of deep water, but is occasionally met with in rock pools. It is of much the same size as *Palæmon squilla*, which it resembles not a little, but is of a somewhat brighter colour, the long antennæ in particular being in life beautifully ringed with scarlet. Like most of the smaller Crustacea, it loses most of its beauty at death, owing to the disappearance of the delicate transparency of tint. In general shape and appearance the Esop prawn resembles the true prawns, but can be distinguished from them by the humped back, and by the different character of the legs and antennules. In these respects it resembles the next genus, *Hippolyte*, much more closely than *Palæmon*, and the student should not fail to notice how closely the three genera resemble one another, and how the Esop prawn stands midway between the other two.

As to the detailed characters of *Pandalus*, notice that the hump-backed appearance is due to the fact that the third abdominal segment is pouch-like, being much longer on the upper than the lower surface, so that the tail cannot be completely straightened. Further, the antennules bear two filaments only instead of three as in *Palæmon*, and one of these is thickened and curiously curved. Again, the first pair of legs end in exceedingly minute chelæ, and the second are slender, thread-like, and of unequal size. The filiform appearance is in part produced by the fact that the antepenultimate segment, which morphologists call the wrist, or carpopodite, is broken up into a number of joints, so that it resembles a whip in appearance.

The Esop prawn may be found not infrequently among the "prawns" brought to market as food.

Much smaller than *Pandalus* or *Palæmon* are the various species of *Hippolyte*, which are common on our shores, but not being large enough for use as food are not well known, and have no common name. The commonest form is *H. varians*, a beautiful little creature, about three-quarters of an inch in length, and showing much variation in colour. It is typically green, but among dark weed brown varieties are common, and in pools lined with Red Algæ the tint may be distinctly reddish. In common with the other members of its genus it has the following characters: Like *Pandalus*, it has a hump-back, which is due to the same cause; the antennules generally resemble those of *Pandalus*, but the thicker filament is much curved, and furnished with numerous bristles; both filaments are short. It differs from *Pandalus* in the nature of the first pair of legs, for these are short, equal, and distinctly chelate; the second and remaining pairs closely resemble the corresponding appendages in *Pandalus*. There is usually a well-developed rostrum, and it is the condition of this structure which is chiefly relied on in the distinction of species. In *H. varians* it is straight, furnished above with one spine near the base, and one near the apex, beneath it is sharply keeled, and bears two spines. The inner filament of the antennules is only very slightly curved. These characters should be sufficient to distinguish this species, which is the only one which can justly be described as common in the littoral zone of the East Coast. On the West, however, and especially the South-west, another species is sometimes extraordinarily abundant. This is *H. cranchii*, which in certain parts of the Devonshire coast seems to occur in every rock pool. In life it is of a delicate green colour, with the appendages ringed with pale blue; but the green colour is very fugitive after death. It reaches about the same length as the preceding species, but the greater breadth of the thorax gives it a much more robust appearance. The rostrum is short, furnished with three teeth above, besides the two in which it ends. Beneath there are no teeth. The two species show very little resemblance to one another. The other species of *Hippolyte* being mostly rare or inhabitants of deep water are beyond our scope.

Very little observation will convince the student that the three genera just described resemble one another very closely, and no difficulty will be found in drawing up a list of their common characters. All differ somewhat markedly from the next genus we have to consider—that which includes the common shrimp (*Crangon vulgaris*). Of this abundant and familiar form it is always easy to obtain specimens. In the tidal streams flowing between the rocks, near the mouths of rivers, in sandy pools, wherever there is abundant sand one may be almost sure of finding this ubiquitous form, darting rapidly hither and thither, or burying itself deep in the sand. In life, as everyone knows, shrimps are sand-coloured, but examination with a lens will show you that although the general tint be dull, the shrimp is minutely speckled with brilliant red-brown spots of singularly beautiful shape. When boiled, the true shrimp does not become bright red, as do many of its allies, but merely pinkish brown, and on this account is often called the brown shrimp as a distinction from the prawns. The common shrimp is the only species of its genus which can be justly described as common on our shores, but as other species do occur, especially on the West, we may take the characters of the genus first, before mentioning those peculiar to *C. vulgaris*. All the true shrimps differ from the prawns in the following characters:—the carapace is somewhat depressed instead of being flattened from side to side, and the rostrum is rudimentary; the abdomen is long and very strong; the antennæ are placed at the outer side of the antennules, and not beneath them; the antennal scale is large, and the filaments of the antennules similar. The legs are peculiar, especially the first pair, which are short and stout, and exhibit the condition described as subchelate. It will have been noticed that when hitherto appendages have been described as ending in chelæ, or forceps, the chelæ have all been of the same structure. That is to say, in each case the last joint ("movable finger") has worked against an immovable prolongation of the preceding joint, which formed the other half of the forceps. In the shrimp the prolongation of the penultimate joint is very minute, and the last joint is bent down sharply upon the preceding joint; this condition is described as sub-chelate. The next pair of legs in the shrimp are very slender and end in chelæ; the remaining legs end in simple claws.

The common shrimp can be recognised by the following special characters. The carapace has three spines only, a median and two lateral; the abdomen is perfectly smooth, and regularly marked with brown spots. It is the largest British member of its genus, and reaches a length of two and a half inches.

The great size of the antennal scales is a very obvious feature of the shrimp, and it is interesting to note that in burying itself it first makes an excavation by rapid movements of the legs, and then completes the process by shovelling sand over the body by means of the antennal scales. It is a matter of common observation how complete the burying process is.

This completes the description of the common types of Natant Decapods. It should be clearly understood that there are other British genera besides those described, but specimens of them are rare in Britain, and have been omitted. The descriptions given above will be sufficient to make plain the general characters of these Crustacea as contrasted with the creeping forms next to be described.

KEY FOR IDENTIFICATION OF CRUSTACEA DESCRIBED IN THIS CHAPTER.

DECAPODA (Crustacea with ten pairs of legs) . . } I. NATANTIA (swimming forms). II. REPTANTIA (creeping forms).

I. NATANTIA. Family Carididæ (shrimps and prawns).

Body depressed, rostrum rudimentary . . . } *Crangon* (common shrimp).

Body compressed, rostrum well developed . . . } *Palæmon.* *Pandalus.* *Hippolyte.*

Antennules with three filaments . . . } *Palæmon* . { Rostrum curved, with eight or nine teeth above, and five or six beneath—*P. serratus.* Rostrum straight, with seven or eight teeth above, and three beneath —*P. squilla.*

Antennules with two filaments . . . } *Pandalus.* *Hippolyte.*

Filaments of antennules long and sub-equal, first pair of legs very long and slender . } *Pandalus* . { Rostrum very long, curved upwards, anterior half without spines, except for a very small one near the apex—*P. annulicornis.*

Filaments of antennules short, one thick and curved, the other slender and straight, first pair of legs short and distinctly chelate . . . } *Hippolyte* . { Rostrum with two spines above and two below—*H. varians.* Rostrum with three spines above, and a terminal notch, none below—*H. cranchii.*

NOTE ON DISTRIBUTION.

Little need be said on this point in addition to what is noted in the text. Prawns, generally speaking, are commoner on the South and West than on the North and East, and *Palæmon serratus*, at least, is not likely to be found on the East Coast. But as the prawns are better adapted for life in the open than between tide-marks, the occurrence of large specimens in the latter situation is somewhat exceptional at any part of the coast. The species of *Hippolyte*, which are small, are common in rock pools, *H. varians* in most places round the coast, *H. cranchii* on the South and West. I found it especially abundant in the shore pools at Lynmouth, on the coast of Devonshire. Other species of *Hippolyte* also occur. The common shrimp is found, where the conditions are favourable, at all parts of the coast.

CHAPTER IX.

THE DECAPOD CRUSTACEA: LOBSTERS, CRAYFISH, AND THEIR ALLIES.

The common lobster and the Norway lobster—Their distribution and characters—Structure and habits of the spiny lobster—Habits of Galathea—Its structure and relation to the porcelain crabs—The two common porcelain crabs—Their structure and habits—The hermit-crabs—The northern stone crab and its relation to the true crabs—The masked crab.

THE Reptant Crustacea form a much larger division than the Natantia, for they include the greater number of the long-tailed forms together with the crabs and their allies. Their classification is a matter of some difficulty, for, as already indicated, although crabs and lobsters seem to be widely separated from one another, yet there are transitional forms which connect them together, and make a sharp division impossible. For our purpose it is, therefore, sufficient if we consider the Reptantia as divided into a number of families, without concerning ourselves with the grouping of these families into larger divisions. Following the same order as with the Natantia, we shall begin with simpler or less specialised forms—those most nearly related to prawns and shrimps.

The first family (Astacidæ) is that to which the crayfishes proper belong. The most important members of it are the fresh-water crayfish (*Astacus fluviatilis*), a beautiful little creature quite outside our sphere; the true lobster (*Homarus vulgaris*), and the Norway lobster (*Nephrops norvegicus*). The last is never found between tide-marks, but is at certain seasons brought to market in large numbers, and is included here because it is readily obtainable, and is so admirably suited for the study of the characters of Crustacea. It is commonly called a crayfish, but this name is applied indiscriminately by fishermen to all the larger long-tailed Crustacea except the true lobster, just as shrimp is applied to the smaller forms. The true lobster does occur between tide-marks, but only at low spring tides, when it may be found under overhanging rocks in the deeper pools, threatening the too eager naturalist with the fate which so nearly overtook the Mayor of Plymouth.

The characters of the family of Astacidæ may be briefly summarised as follows. The body is arched and slightly compressed from side to side. The carapace has a distinct cervical or neck furrow, absent in Carididæ, and bears a well-developed rostrum. The antennal scale is relatively smaller than in the Carididæ, and the antennæ themselves are placed beneath the antennules, not side by side with them as in the higher Carididæ. As in the latter, the third maxillipede is elongated and leg-like. Each of the first three legs ends in forceps, a condition paralleled in the Carididæ in the shrimp *Peneus*, but the first pair are much stronger than the others, forming powerful weapons of offence and defence. The tail is long and strong, and ends in a powerful tail fan; the other abdominal appendages are more or less rudimentary, but the first pair in the male are converted into hardened styles. As already indicated, the Astacidæ stand much nearer *Peneus* and its allies than any of the Natant genera which we have described in detail. We must suppose that the higher Natantia (true shrimps and prawns) and the Astacidæ have both been derived, along different lines, from ancestral forms which resembled *Peneus*.

As we have seen, the three commonest forms included under Astacidæ are the fresh-water crayfish, the true lobster, and the Norway lobster, and it is interesting to note that although they can be distinguished with perfect ease by the untrained eye, yet minute scrutiny does not bring to light a great number of marked differences: there is much general resemblance in structure. It is also interesting to note that while there are a great number of fresh-water crayfishes, widely distributed over the world, there are only relatively few species of *Homarus* and *Nephrops*.

The true lobster (*Homarus vulgaris*) is especially characterised by its relatively short rostrum, which only slightly exceeds the peduncle of the antennæ in length, and by the fact that this rostrum bears three teeth on each side, and none beneath. The very large chelipeds have the wrist (carpopodite) furnished with four or five large conical teeth on the upper border. Lobsters, as is well known, are usually brownish blue in colour, marbled with white; but there is considerable variation in colour, full-red varieties not being unknown. They do not inhabit very deep water, and are usually caught off rocky coasts. According to the fishermen they are very sedentary animals, rarely venturing far from their particular haunts. This observation depends upon the fact that they have a peculiar tendency to exhibit local variations in colour, which is said to enable experts to name the locality from which particular specimens have come. Thick-shelled forms like the lobster cannot, of course, change colour according to their surroundings, as delicate forms like *Hippolyte* can; so that if, as is generally supposed, the colour of the lobster has a direct relation to that of its environment, the adaptation must have taken place when the lobster was very young, or must be the result of a process of selection in each locality.

Lobsters are very widely distributed around the coasts of Europe, and it is said that five or six millions are annually taken in Northern Europe alone. Whatever be the exact figures, there is no doubt that in most localities the incessant persecution has greatly diminished their numbers, and that in spite of the fact that the female lays 12,000 eggs at a time, and carries them about with her till they hatch. Recently efforts have been made to protect what is grotesquely called the "hen-lobster in berry"—that is to say, the female with eggs, during at least a part of the year.

The Norway lobster, with its delicate colouring and thin, elaborately sculptured shell, is a much more graceful animal than the true lobster, and from its shape one would expect it to be capable of much more rapid locomotion. It never occurs near the shore, but lives in deep water, whence it is obtained by trawlers. Though typically a Norwegian species, it extends also in diminished numbers to the Mediterranean, and is the object of an extensive fishery on the east coast of Scotland. It is curious to note that although at certain seasons many hundreds are daily brought to market in Edinburgh, almost all these are males, and an egg-bearing female is very rarely seen; one would therefore expect that a rapid diminution of numbers is less likely to occur than in the case of the lobster.

In the Norway lobster the rostrum is long, slightly exceeding in length the peduncle or stalk of the antennæ; it is furnished with three teeth at either side, and is hairy beneath. The anterior part of the carapace (gastric region) is furnished with seven longitudinal rows of spines. The abdomen is beautifully marked, the markings being accentuated by the distribution of the fine hairs. The great claws differ much in shape from those of either lobster or crayfish, for the propodite or hand is four-sided, the margins being emphasised by the development of rows of spines. The whole limb is elongated and slender, very different from the broad and heavy chelipeds of *Homarus*. In colour *Nephrops* is a delicate orange-red with brown hairs. It is much smaller than the lobster, being usually seven to eight inches in length. Young specimens may sometimes be obtained from the trawlers, and make most charming pets. They live well in confinement, but have most voracious appetites, quite out of harmony with the fairy-like form and delicate colouring. In such specimens the eyes are exceedingly conspicuous, and their peculiar "kidney" shape should be noticed. It is this peculiarity which gives the animal its scientific name (*Nephrops* = kidney-eyed).

It may, perhaps, be well to note here, for the sake of future reference, the names given by systematists to the typical segments of the legs of Crustacea. Beginning at the outer end these are: dactylopodite, or finger; propodite, or hand; carpopodite, or wrist; meropodite, or arm; and less important, ischiopodite, basipodite, and basal coxopodite, seven pieces in all.

The next family is that of the *Palinuridæ*, including only one British form, the splendid rock lobster or spiny lobster (*Palinurus vulgaris*), a Mediterranean species found on the South and West of England and off the coasts of Ireland. Like many of its allies it is sometimes called a crayfish, and is esteemed as an article of food in those districts in which it occurs. It is a handsome creature, of reddish brown colour mottled with white, with a strong superficial resemblance to the true lobster, from which it differs in certain very marked respects. As indicated by its common name, it frequents rocky coasts, the neighbourhood of Lundy being an especially favoured spot. It does not occur on the East Coast.

The point which will first strike the observer in *Palinurus* is the total absence of the great forceps so characteristic of lobster and crayfish. All the legs are similar, and terminate in simply pointed claws, though the first pair show in rudiment the condition described as sub-chelate for the shrimp (p. 169). Again, the antennules are half as long as the body, but the length is given by the great elongation of the peduncles, the flagella being exceedingly short. The antennæ are very long, longer than the body, and are borne on very stout and spinose peduncles; the scale is entirely absent. The carapace is very densely coated with spines, of which two are very large and project forward over the eyes, but the rostrum is very small. In both sexes the first pair of abdominal appendages is absent, the others are simple in the male and two-branched in the female. These are only a few of the peculiar characters of *Palinurus*, which separate it so markedly from the Astacidæ; the absence of the great chelæ is a point of special interest. It lives chiefly upon the little Molluscs which cluster about the rocks, and is one of the few Crustacea capable of making distinct sounds, produced by rubbing movements of a specially spiny part of the stalks of the antennæ.

The Reptant Crustacea with which we have been hitherto concerned have been large forms showing many points of interest, but which at most can only be hoped for very occasionally on the tidal rocks, and are therefore somewhat beyond our proper sphere. On the other hand, the forms to which we have now to turn are abundant everywhere on the rocks, can sometimes be kept for a considerable period in confinement, and are therefore objects of greater interest to us. These forms are the species of *Galathea*, and the porcelain crabs (*Porcellana*). We shall consider these two genera together as forming one family, for though sometimes widely separated, they show in many points great structural resemblance. They are often separated, because the porcelain crabs are in popular view crabs, while the *Galathea* would popularly be described as a kind of lobster. We shall see how nearly the two resemble one another, so that this family, like not a few others, may be described as linking crabs to lobsters.

First as to *Galathea*—when stooping over a rock pool paved with promising stones, you will not unlikely see darting through the water an animal whose movements are so swift that it seems to be gone before you are well aware of its presence. Momentary as the impression is, however, it will probably have convinced you that the motion is unlike that of a fish. If you employ all the artifices at your disposal, and by draining the pool, removing its stones, and searching its furthest recesses, compel the object of your search to reveal himself, you will probably find a *Galathea*. Even so, however, seeing is not catching, and there is many a slip between the *Galathea* and the collecting bottle. I well remember the first specimen I had the fortune to catch. The chase had been long, and the pool was deep, but at last the wary Crustacean had been got into a corner, and heedless of her footing the would-be captor made a sudden dart. It was successful, and for one joyful instant I held the prize in my grasp. But it was just an instant; there was a sudden jerk and a splash, and I was left in the pool with one great claw in my hand, while the *Galathea* twiddled his whiskers in insolent contempt from an inaccessible crevice. I then learnt that the "power of autotomy is possessed by the higher Crustacea to a very marked degree," but that information, though valuable, did not bring back the *Galathea*. Nor was I much consoled on learning further that "the autotomy is reflex and due to the stimulation of the sensory nerve," or in plain English that if I hadn't pinched the claw the *Galathea* wouldn't have thrown it off, for I defy anyone to catch a *Galathea* by one leg while floundering in the water, and not pinch that leg. It is therefore better, on the whole, not to catch your specimens by the legs, but to try and gently persuade them to enter a net or collecting bottle.

When caught, you will find that *Galathea* at first sight somewhat resembles a very short and broad spiny lobster. The colour is variable, but in the commonest species, *G. squamifera*, which attains a length of about three inches, the prevailing tint is usually brownish blue. Very young specimens are, however, not infrequently brilliantly marked with bright blue and red.

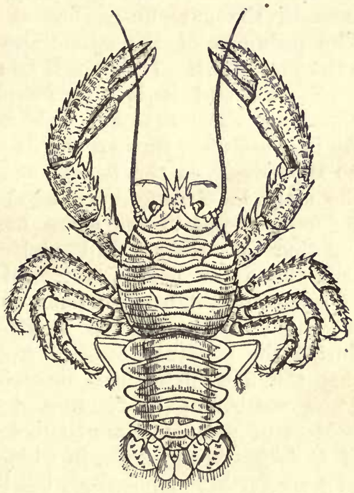

FIG. 51.—Scaly squat-lobster (*Galathea squamifera*). The animal is figured in a somewhat unnatural position, in order to show the structure of the tail, and afford a basis of comparison with the lobster, Fig. 48.

In marked contrast to *Palinurus*, we find that *Galathea* is furnished with a pair of long chelipeds, forming the first pair of legs. In so far it resembles the true lobster and crayfish, but it will be noticed that only the first pair of legs bear forceps, not several pairs, as in crayfish and lobster. With the gradual increase in the creeping habit, and the diminution of the power of swimming, the next two pairs of legs take on as their primary function that of supporting the body, and lose their power of prehension. The student should also not fail to notice that with the broadening of the body, first obvious in *Galathea*, the insertion of legs also moves outwards, so that the body becomes more definitely adapted to the creeping habit. It may, however, be objected that it is not obvious in what respects *Galathea* shows a diminished power of swimming, in view of the frequent difficulty in effecting its capture. That it is not so good a swimmer as the true lobster can yet be proved both from structure and habit. As to habit, *Galathea* habitually creeps on its walking legs, and only darts backwards on the sudden advent of danger. In repose it keeps the tail bent—a trifling point, but one fruitful in consequences. Then as to structure, compared with the lobster the tail is much shortened, relatively to the cephalothorax, its muscles are greatly reduced, and in short it is mechanically unfitted to function as an organ of locomotion for more than a limited period.

Among the other interesting points of structure shown by *Galathea* are the following. The antennæ are not beneath the antennules, but at the outer side of them. The peduncle of the antennules is long, and the flagella extremely short. This it will be remembered occurs also in *Palinurus*, and it is also found in all the forms above *Galathea*. The antennal scale is absent, as in *Palinurus*. As in *Palinurus*, further, the first abdominal segment bears no appendages in the female, and very rudimentary ones in the male, in *Galathea* this segment is indeed considerably reduced, owing to the sharp flexion of the body at the junction of thorax and abdomen. This flexion and reduction is, of course, universal among the crabs, and is of some interest because some naturalists would regard the reduction as directly the result of the pressure exerted during the bending process. But it is important to notice that the first abdominal appendages have disappeared in *Palinurus* before the bending of the abdomen has begun.

Most of the above are characters indicating the approach of *Galathea* to the crabs, in which these structural peculiarities are further emphasised; but in addition *Galathea* shows certain special peculiarities. Note especially the condition of the last pair of legs. These are reduced to mere rods with a terminal brush of hairs and rudimentary chelæ, and are habitually carried tucked underneath the gill-cover. In the figure they are shown spread out. The gill-cover, it will be noted, is no longer vertical, as in the crayfish, but is now oblique in position, and separated from the shield by a suture. The well-developed rostrum with spines characteristic of the species should also be noticed, and the reduction of the abdominal appendages, whose only function seems now to be to carry the eggs in the female.

Two species of *Galathea* are common on our shores. The commoner is *G. squamifera*, while the larger, *G. strigosa*, is more usually found in deeper water.

The first-named species has a short rostrum ending in a spine, and bearing four spines on each side, the last being the smallest. The chelæ bear spines, but only on the inner margin of the meropodite and carpopodite (arm and wrist), and the outer margin of the propodite (hand).

In the spinous *Galathea* (*G. strigosa*) the rostrum has only three teeth on each side, and the great claws bear numerous spines on both margins. The two species are very neatly distinguished by the structure of the maxillipedes, as will be seen on reference to the table at the end of the chapter.

The next forms to be considered after *Galathea* are the little porcelain-crabs, very different in appearance from *Galathea*, less active and less beautiful, but no less interesting. As already indicated, the porcelain-crabs are sometimes widely separated from *Galathea*, but we shall consider both here as belonging to the same family (Porcellanidæ), for they seem to be closely related.

FIG 52.—Hairy porcelain-crab (*Porcellana platycheles*). The tail is in the natural position, that is, completely bent beneath the body.

We have two British species of *Porcellana*, both very abundant, and occurring on the shore rocks. The larger, *P. platycheles*, is to be sought under stones in muddy pools. The crab does not live in mud, so that the stones must be those which from their position have a cavity beneath them, and the likeliest pools are those traversed by a little stream of water. Turn over such stones, and you will see on the upturned surface small muddy crabs with large flattened chelipeds, whose one method of defence seems to be the passive one of crouching down, with the curious great claws, which are densely fringed with hair, arranged at such an angle that they resemble nothing so much as a flattened pebble adhering to the stone by means of a layer of mud. It is curious that although very common, and found considerably above low-tide mark, these crabs are familiar to very few people. This is partly because the localities which they haunt are not those in which the collector usually lingers, partly no doubt because the habit of crouching down and the coating of mud make them very inconspicuous.

The other species, *P. longicornis*, though smaller, is much more conspicuous and brighter in tint. It is found under stones also, but not where there is mud, and usually inhabits deeper water than its hairy congener. My best specimens have been obtained from the roots of *Laminaria*, either pulled out of the deeper pools, or cast on shore after storms. The last constitutes a very important source of supply for the smaller and rarer Crustacea. After many an easterly gale the shore is strewn with giants from the marine forests, and every plant has brought away with it countless forms of animal life which once lodged in its roots, stems, and fronds.

Presuming, then, that you have obtained specimens of both crabs, and that by a dexterous use of a camel's-hair pencil you have removed a portion of the mud from the hairs of *P. platycheles*, and so succeeded in revealing its shape to some extent, we will consider the characters of the genus.

Both differ very markedly from *Galathea* in the shape of the carapace, for it is almost circular and much depressed —in other words, truly crab-like. The abdomen is completely flexed, as in crabs in general, but it is large, retains its seven distinct parts, and ends in a distinct, though small and delicate, tail fin. You should not fail to notice that, as in *Galathea*, the telson, or tail-piece, is curiously marked, being composed of several pieces. As to the appendages, the small antennules and the very long antennæ in essentials resemble those of *Galathea*. The third maxillipedes are very interesting, because they present some general resemblance to those of *Galathea* and the lobster; but yet in the expansion of their basal joints they show an approach to the shutter-like structure seen in the true crabs. As a special peculiarity they exhibit a dense fringe of long hair on the inner margin of their terminal joints. The structure of the great claws differs in the two species, but in both cases they are so modified by the hollowing out of the wrist (carpopodite), that they can be held in a retracted position (see Fig. 52). This is characteristic of the crabs as compared with the long-tailed forms, which carry their chelipeds outstretched. The next three pairs of appendages are walking legs, used for the support of the body. As in *Galathea*, the last pair of legs is modified to form two slender rod-like structures, habitually kept folded beneath the lateral margin of the carapace, and terminating in minute chelæ with a brush of hairs. In the figure they are represented in the unfolded condition. Besides the terminal swimmerets, the abdomen in the female bears four pairs of slender hairy appendages used for carrying the eggs, while in the male there is only a single pair of slender rods. The reduction of the abdominal appendages in the male should be noticed, as it is very characteristic of crabs compared with long-tailed forms. The appendages of the male belong to the second abdominal segment, and the appendages of the first segment are also absent in the female, as in crabs. The porcelain-crabs are passive little creatures as a general rule, showing marked preference for secluded situations, and clinging tightly to stones or weed when disturbed. In spite, however, of the crab-like appearance, they still retain the power of swimming, as may be often seen in captivity in the minute porcelain-crab. Occasionally this species gives up its sedentary habits and takes to active swimming through the water. The motion is, of course, backwards, and it is very curious to notice that although it begins its journey in the normal position, the weight of the heavy claws seems to invert the body, and it very speedily falls over on its back. It is a very interesting sight to see the little creatures lying on their backs in the water and propelling themselves backwards by vigorous jerks. It is obvious that under such circumstances the long antennæ are of much use in helping to direct the movements and avoid collisions. I have never seen the hairy porcelain-crab swim, and if it does so the heavier claws must handicap it considerably, and make the movement exceedingly fatiguing. The whole shape of the claws is considerably more crab-like than in the other species, and from the nature of its habitat one would not expect that swimming would be frequently indulged in. Both it and the smaller species, when turned on their backs, flap their tails to assist their efforts to regain the natural position. In specimens kept in confinement the dense fringe of hairs on the third maxillipedes should also be noticed. In the hairy porcelain-crab the hairs are used as a comb to clean the antennæ and antennules from any adhering particles of mud—a very necessary matter in animals living in muddy situations. Both species have also a habit of holding the fringes out at arm's length, and then sweeping them inwards; it is probable that in doing this food-particles are entangled among the hairs, which thus serve as fishing-nets.

There is no difficulty in distinguishing between the two species of porcelain-crabs, for they are very unlike one another in appearance.

In *P. platycheles* the carapace is usually about half an inch broad, and the length of the great claws is somewhat over an inch. The upper surface in life is so densely covered with fine mud that no colour is visible; but the under surface is whitish, and when carefully cleaned the upper has a reddish tint. The hairy porcelain-crab, as it is called, is a very interesting species on account of its adaptations to a life in turbid water. It has been proved by experiment that, hardy as the common shore crab is, water containing mud is extraordinarily fatal to it. This is due to the fact that the gills, as in all Crustacea, are external structures, though they lie within a protecting gill-chamber. In consequence they are exposed to the action of the mud in the water of respiration. The particles settle on their surface, and produce an effect which is, in a rough way, analogous to the effect produced by deposits of dust in our lungs, and this speedily asphyxiates the crab. If, therefore, a crab is to live in sand or mud, it must have a special mechanism to prevent the particles gaining access to the gills. This is generally effected by the development of hairs, placed on the general surface of the body, but especially on the path of the respiratory current. The chief point of entrance of the water to the gill-chamber is in most crabs at the base of the great claws. If you examine *Porcellana platycheles* when at rest on a stone, you will see that the legs in general, but the great claws in particular, are densely fringed with hairs. These hairs, as is easily seen, act as sieves, entangling the fine particles, and allowing pure water only to pass through them. The sifting action of the hairs is greatly increased by the fact that they are branched and serrated, a point easily demonstrated by microscopic examination. The third segment of the rudimentary legs is also hairy, and in life lies at the sides of the carapace, preventing the access of mud to the posterior part of the gill-chamber. These legs are also periodically unfolded, and their terminal brush of hairs used to clean out the groove and remove any adhering particles. This curious manœuvre may often be seen in forms kept in confinement. We have already noticed the similar cleansing process practised on the sensitive feelers.

The special characteristics of *P. platycheles* are its general hairiness, and the large size and flattened shape of the chelipeds. The front of the carapace is furnished with three triangular teeth, the middle one being the largest.

The minute porcelain-crab (*P. longicornis*) usually measures in large specimens under a quarter of an inch across the carapace. In the males the colour is bright red, but is somewhat less brilliant in the females. The great claws are of unequal size, and are more or less prismatic in shape. Like the rest of the body, they are quite smooth and devoid of hairs—a marked contrast to the preceding species. In the male, however, the "fingers" (chelæ) of the left great claw are curiously twisted, and covered internally with a dense pubescence of brown colour. The "fingers" of the female are less markedly twisted, and the pubescence is absent. In both sexes the antennæ are about twice as long as the carapace, and the front of the carapace is furnished with three teeth, of which the middle one is deeply grooved.

Both the porcelain-crabs are abundant at most parts of the shore, and live well in confinement.

The next family is the Paguridæ, including our own very curious hermit-crabs and the cocoanut-crabs of the tropics. All these have long abdomens, like true Macrura, but the abdomen is more or less soft, unsegmented, and usually unsymmetrical. Most of the forms have in consequence acquired the curious habit of availing themselves of the shells of other animals, usually Gasteropods, and carrying these about with them as a house. The appendages of the abdomen are correspondingly reduced, the chelipeds are very large and usually of unequal size, and the two last pairs of walking legs are reduced.

The true hermit- or soldier-crabs belong to the very large genus *Pagurus*, often divided into a number of sub-genera; it will be sufficient for us to consider the British species as belonging to *Pagurus* itself, although they strictly fall into the sub-genus *Eupagurus*.

On the East Coast there is only one common species near the shore, and that is *P. bernhardus*, or Bernard the Hermit, as it is commonly called abroad. Of this form small specimens are abundant, often extraordinarily abundant, in all shore pools. In the Firth of Forth after storms the beach is sometimes literally paved with hermits, and every

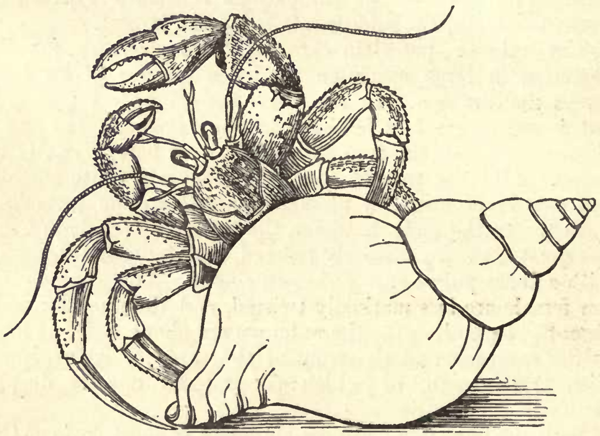

FIG. 53.—Common hermit-crab (*Pagurus bernhardus*) in the shell of the whelk.

rock pool has its representatives. These inshore forms inhabit the shells of the different species of periwinkle, *Trochus*, *Purpura*, and of the smaller whelks, often much damaged specimens — the broken top of a very large "buckie" seems indeed to arouse specially keen competition. The size of the hermits depends upon that of their habitation, for the hermit changes its shell as it grows, so that all these specimens are necessarily small; the fact that many of them will be found to be carrying eggs shows, however, that maturity does not depend on size alone. When removed from their shells it will be seen that all these forms have an abdomen of *blue* colour. With these the hermit-crabs dredged from deep water, or cast ashore after storms, seem at first sight to be markedly contrasted. They inhabit the large shells of full-grown specimens of *Fusus* or *Buccinum*, shells often nearly six inches in length and heavy in proportion, and the hermits reach a size commensurate with that of their dwellings. The abdomen is a deep brick-red, and the rest of the body deeper in tint than in the shallow-water forms. It requires some study to convince one's self that such hermits are not specifically distinct from the more familiar forms found on the tidal rocks, and the fact that the latter become mature in shallow water, almost justifies one in speaking of them as a variety.

One other point of interest about the hermits is their habit of living in symbiosis or partnership with other animals. In certain localities the hermits very commonly inhabit shells covered externally by the beautiful zoophyte *Hydractinia*. This seems, however, to depend very largely upon the locality. Most hermits from deep water have, as companions *within* their shells, one or more specimens of a very beautiful worm, *Nereis fucata* (see p. 106). So common is this association, that in some places fishermen catch the hermits, and turn them out of their shells for the sake of the partner worms, which are used as bait. It is not easy to see what the hermit gains by the presence of the worm, but at least it is not injured by it, as it is by another common associate, the parasitic *Peltogaster*, which hangs like a sac from the under surface of the abdomen in very many hermit-crabs.

As everyone who has tried to keep hermits in confinement knows, they are exceedingly sensitive to unfavourable conditions, especially to a diminished oxidation of the water. The first sign of discomfort displayed is the tendency to quit the shell, or to change rapidly from one shell to another, and this restlessness is usually quickly followed by death. It is difficult to say whether this delicacy of constitution is due to a difficulty in respiration produced by the shell, or to that racial decadence which has made the appropriation of the shell necessary. If, however, you wish to keep the hermits alive, they must be allowed a large bulk of water, as frequently renewed as possible. Under such conditions they form very interesting pets; the explorations in all directions carried on by the long antennæ, the flickering movements of the antennules, the sudden recoil within the shell at the approach of danger, and the peculiar gait, should all be noticed. Also the fact that just as the original owner of the shell was an unsymmetrical, twisted animal, so also the body of its present possessor is distinctly lopsided and coiled. The want of symmetry is indicated externally in the inequality of the great claws, but is more obvious when the dying hermit drags its soft body out of the stolen shell, and shows all its twisted length.

In the dead specimens the following points can be made out. Though the great claws and walking legs are strongly calcified, the rest of the body is soft and thin-skinned. The carapace is delicate, and does not cover the last thoracic ring, which is free, as it is in the last family. The abdomen is much longer than the cephalothorax, and is twisted to the right side. The antennæ are very long, are placed beneath the antennules, and have a rudimentary scale. In their general structure the antennules resemble those of the last family, that is to say, their filaments are short as contrasted with the long ones of lobster and crayfish, and the upper is thickened and fringed with hair. The eyes have very long stalks and are very mobile. We have already spoken of the inequality of the great claws; the next two pairs of legs are simple, very long, and strongly calcified; they are used for locomotion. The last two pairs, on the other hand, are shortened and greatly reduced. They do not project from the shell, and as in the case of the last pair of legs in the preceding family, terminate in very rudimentary chelæ. The abdomen has mere traces of calcification on its upper surface, but terminates in a distinctly calcified telson, which shows some signs of being, as in the preceding family, calcified in several pieces. In both sexes the last pair of abdominal appendages is present; the left is much better developed than the right, and forms a sickle-shaped structure which attaches the hermit to its stolen shell. The right appendage is smaller, but is also hard and of somewhat similar shape. Besides these paired appendages the left side of the abdomen in the female bears four unpaired appendages, of which three are anterior, very hairy, and used for carrying the eggs. The fourth, separated by a long interval, is very much smaller. In the male there are three unpaired appendages of small size. The unsymmetrical condition of the abdominal appendages in *Pagurus* is a point of much importance.

We shall only mention here two species of *Pagurus*, the common hermit, *P. bernhardus*, and the closely related *P. prideauxii* of the West. "Bernard the Hermit" is recognised by the fact that the great claws have their surface covered with spinous tubercles and granules, and that the terminal segment of the walking legs is twisted and expanded. It is abundant everywhere.

The *P. prideauxii* of the West Coast is very similar to the common hermit, but the chelæ are less tuberculated, and the last joint of the walking legs is scarcely twisted, not flattened, and grooved at each side. This form does not occur on the East Coast, but is included here on account of the interesting fact that it almost always bears the sea-anemone *Adamsia palliata* on the back of its shell—another interesting case of commensalism in these hermits. In the Clyde, and on other parts of the West and South, *P. prideauxii* and its messmate are abundant.

The other numerous British species of *Pagurus* mostly live in deep water, or are confined to the South and West.

The hermit-crabs possess so many obvious peculiarities that they are quite unmistakable, but the next crab we shall consider, though probably nearly related to the hermits, is not infrequently erroneously described as a spider-crab. This is *Lithodes maia*, the northern stone-crab, an animal interesting alike in its distribution, its structure, and its superficial resemblance to the true spider-crab *Maia*. As the common name indicates, it is a northern species, one of the few forms whose presence on the East Coast compensates for the absence of the rich Mediterranean fauna of the West and South. It attains a large size—a span of twenty inches, with a breadth of carapace of four inches, and inhabits deep water. Though not a littoral form, it is, however, included here because of its interest, and because it may be not infrequently obtained from friendly fishermen, and occasionally finds its way as a curiosity into fishmongers' shops. Anyone accustomed to the Crustacea of the West seeing a specimen for the first time, and noting the length of leg, the triangular carapace, and the dense coating of spines, is likely at once to pronounce it to be a spiny spider-crab. Not infrequently he writes to the newspapers to proclaim the fact; the spiny spider-crab as an inhabitant of the North-east may indeed be relied upon to appear as regularly as the nightingale, the humming-bird, the sea-serpent, and the other phenomena of the dead season.

If you are fortunate enough to obtain a specimen, you may easily enough demonstrate to yourself the reasons why *Lithodes* is not a spider-crab, but is relegated to a family of its own, the Lithodidæ, which is placed at a considerable distance from the true crabs.

The stone-crab has a triangular spiny carapace prolonged into a long rostrum, which bears eight spines. There are no orbits, or eye-sockets, and the eyes are placed at the inner side of the antennæ (contrast crabs). The antennules lie beneath the eyes, and have a very long stalk, and very short flagella (cf. hermit-crabs). The antennæ are long, and placed not in a complete socket, but in a gap between a spine on the carapace and one on the anterior end of the gill-cover (cf. *Porcellana*, and contrast crabs). The gill-cover itself is nearly vertical (cf. *Pagurus* and *Galathea*), and divided into several pieces. As in *Pagurus*, the last ring of the thorax is movable, and is not covered by the carapace, and its appendages are greatly reduced, and concealed in life beneath the carapace. As in *Pagurus* and *Galathea*, the third maxillipede is completely leg-like, and does not form an operculum, as in the true crabs. The first pair of legs only are truly chelate, the others are very long. Both carapace and legs are spiny, and are of the same dull red colour.

So far *Lithodes* has only been seen to resemble *Pagurus* in those points in which *Pagurus* itself resembles *Galathea*, or even more distant forms, but in the structure of the abdomen, *Lithodes*, on the other hand, shows a striking affinity to *Pagurus*, and to *Pagurus* alone. In *Lithodes*, as in *Pagurus*, the abdomen is incompletely calcified, the first two segments are large and visible on the dorsal surface, the remaining segments are permanently flexed beneath the thorax. In the female these segments are markedly unsymmetrical, the left side being better developed than the right, and bearing four unpaired appendages used for carrying the eggs (cf. *Pagurus*). In the male the abdomen is symmetrical, but uncalcified, except for small lateral plates.

The student should not fail to notice that the four genera just discussed—*Galathea*, *Porcellana*, *Pagurus*, *Lithodes*—show in several respects close interrelationship. The point of special interest, however, is that they fall into two sets—*Galathea* and *Porcellana* on the one side, and *Pagurus* and *Lithodes* on the other—and that in each set we have a long-tailed (macrurous) form (*Galathea* in the one and *Pagurus* in the other) and a short-tailed form (*Porcellana* and *Lithodes*), the brachyurous characters having been acquired independently in the two cases. The fact will serve to illustrate what is meant by saying that the Decapods cannot be logically classified into Brachyura and Macrura, for not only are forms like *Galathea* and *Porcellana* transitional between the two, but the brachyurous habit seems to have been acquired independently in several groups, and the rigorous application of the classification must result in the separation of closely allied forms. Thus if we put porcelain-crabs and the stone-crab together among other crabs, as is often done, we necessarily ignore the fact that they are more closely allied to *Galathea* and the hermit-crab respectively than to one another.

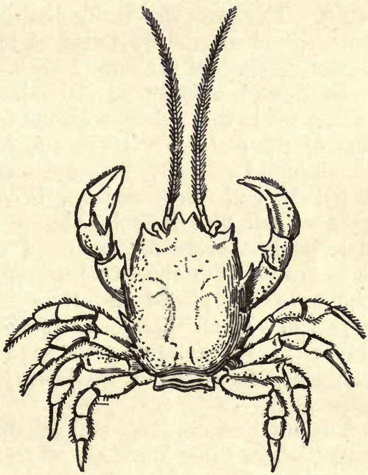

FIG. 54.—Masked crab (*Corystes cassivelaunus*). In part after Herbst.

The next form to be considered is the pretty little masked crab (see Fig. 54), *Corystes cassivelaunus*, belonging to the family Corystidæ, which includes only one other British genus. The masked crab is not very often found between tide-marks, as it usually lives in sand in fairly deep water, but it is a species very commonly cast upon the shore after storms, and may often be found even in summer among the dried masses of wreckage at high-tide mark. The not very appropriate English name was given to it by Bell because of the fact that the regions of the carapace are very distinctly marked, and their grooves are so arranged as to form a somewhat indistinct outline of a man's face. This is only apparent in fresh specimens, and at times is considerably more like a lion than a man. Fresh specimens are pale red in colour, but the colour soon fades to bluish white. In length the carapace usually measures rather over an inch, and it is one-third longer than broad. The sexes are easily distinguished, for while in the male the chelipeds are twice as long as the body, in the female they are of the same length. Further, as in the true crabs, there is a fusion of abdominal segments in the male, so that while the abdomen of the female has several pieces, that of the male only appears to have five. As in all the remaining Decapods, the abdomen is kept permanently flexed beneath the carapace, is very small, and without trace of tail fin; it is broader in the female than in the male, and it bears four pairs of egg-carrying appendages, as compared with the two pairs of small rods in the male. The eyes are placed in orbits into which they can be retracted. In all these respects *Corystes* resembles the true crabs; in the following it resembles the long-tailed or anomalous forms which we have just been considering, or is peculiar.

The antennæ are long, and are supported on long, flexible stalks, whose three joints are all freely movable and inserted at such angles as to bring the two antennæ very close to one another. They are placed beneath the eyes, the orbits of which would be widely open below were it not for the basal joint of the antennal peduncle. The third maxillipedes are long and narrow, but in the reduced size and method of insertion of the three terminal joints they recall those of true crabs. The first two segments of the abdomen are visible on the dorsal surface, and the first is much better developed than in crabs, in which it is more or less reduced.

The masked crab is very easily recognised owing to the peculiarly elongated shape of the carapace, which terminates anteriorly in a deeply notched rostrum, and is furnished with three distinct spines. These points are readily made out in the figure. The elongated antennæ are also peculiar and characteristic. As already indicated, the nature of their insertion is such that the inner surfaces of their flagella are, or can be, closely apposed. These apposed surfaces are densely fringed with hair, and, according to Mr. Garstang, the respiratory current is at least at times downward through the tube formed by the antennæ. It will be recollected that in Crustacea in general the gills are washed by a constant stream of water which enters the gill-chamber at or near its posterior end, and leaves it anteriorly near the mouth. We have already noticed in the mud-loving *Porcellana platycheles* that the numerous hairs covering the body sift the mud from the incoming water, and so protect the delicate gills from injury. The masked crab usually lives buried in sand, with only its long feelers protruding. It is obvious that in this position it is almost impossible that the respiratory current should be of the usual postero-anterior type, and we therefore find that it is at least at times reversed, entering at the anterior end of the gill-chamber after passing down the antennal tube, and leaving at its posterior end. The dense hairy fringe of the antennæ sifts out the particles of sand just as the mud is sifted out in *Porcellana.* The great flexibility of the antennal stalks also permits of the periodic cleaning of the antennæ by the drawing of one over the hairy surface of the other.

It is interesting to note that another member of the family Corystidæ, *Atelecyclus heterodon,* also occurring on British coasts, approaches both in appearance and in structure the crabs much more nearly than does *Corystes* itself It is exclusively an inhabitant of deep water.

KEY FOR IDENTIFICATION OF ABOVE CRUSTACEA.

II. REPTANTIA, creeping forms including lobsters, hermit-crabs and their allies, and true crabs (see next chapter). For full definition of Reptantia, see p. 163.

Of the five pairs of legs, three bear forceps (chelæ)			1. Fam. Astacidæ.
None of the legs bear forceps			2. Fam. Palinuridæ.
One pair of legs only with forceps. Last pair of legs or last two pairs aborted	Tail fan present, abdomen symmetrical		3. Fam. Porcellanidæ.
	No tail fan, abdomen unsymmetrical	Tail long and soft	4. Fam. Paguridæ.
		Tail inturned	5. Fam. Lithodidæ.
One pair of legs only with forceps. All legs normal			6. Fam. Corystidæ (distinguished from true crabs by long antennæ and leg-like maxillipedes).

1. Fam. Astacidæ. Long-tailed forms with large antennal scale	Rostrum short, eyes rounded	Common lobster, *Homarus vulgaris*. For specific characters see text.
	Rostrum long, eyes kidney-shaped	Norway lobster, *Nephrops norvegicus*. See text.
2. Fam. Palinuridæ	Spiny forms with long antennules and no antennal scale	Rock lobster, *Palinurus vulgaris*, the only British species.
3. Fam. Porcellanidæ. Last pair of legs reduced to rods	Carapace ovate, with distinct rostrum—*Galathea*	In *G. squamifera* the meropodite (p. 174) is longer than the ischiopodite, and bears one large terminal spine and five little ones.
		In *G. strigosa* the ischiopodite is longer than the meropodite, which bears two spines.
	Carapace nearly circular, without distinct rostrum — *Porcellana*	In *P. platycheles* the body, and especially the chelipeds, are covered with hair.
		In *P. longicornis* the body and chelipeds are smooth.

4. Fam. Paguridæ. Abdomen long and soft, sheltered within Mollusc shell .	Chelipeds of unequal size, the right the larger —*Eupagurus* .	In *Eupagurus bernhardus* the chelipeds bear spinous tubercles. In *E. prideauxii* they are less tuberculated.
5. Fam. Lithodidæ. Abdomen inturned, but incompletely calcified . .	Rostrum long, last pair of legs rudimentary — *Lithodes* . .	Only British species, *Lithodes maia.*
6. Fam. Corystidæ. Antennæ long and hairy .	Carapace ovate—*Corystes* . .	Only British species, *Corystes cassivelaunus*, the masked crab.
	Carapace circular —*Atelecyclus* .	Only British species, *A. heterodon.*

NOTE ON DISTRIBUTION.

There is much that is interesting in regard to the distribution of the Crustacea mentioned in this chapter. While the common lobster occurs everywhere in suitable localities, the rock lobster (*Palinurus*) only occurs on the South and West, and is most abundant in the South. On the other hand, the Norway lobster, so abundant off the East Coast of Scotland, is rare in the South and South-west of England. On the East Coast, *e.g.* at St. Andrews, the scaly Galathea (*G. squamifera*) is the only species of *Galathea* found between tide-marks; at places like Ilfracombe and Torquay *G. strigosa* and other species are to be found there. The porcelain-crabs seem to occur wherever the conditions are favourable. Of the hermit-crabs the common one occurs everywhere, while *E. prideauxii* is confined to the South and West, where, however, it does not occur between tide-marks. The northern stone-crab (*Lithodes*) is confined to the Northern parts of our area, and is especially abundant off Aberdeen, where it reaches a great size. The masked crab and its ally *Atelecyclus* occur at most parts of the coast where the conditions are favourable.

CHAPTER X.

THE DECAPOD CRUSTACEA—THE TRUE CRABS.

Common spider-crabs—Their coating of weed—The general characters —The edible crab—Its distribution and habits—The shore crab—Different kinds of swimming crabs—The pea-crab—Movements of the Decapod Crustacea—Process of moulting—Development of Crustacea.

IN this chapter we have to consider the true crabs, one of the most interesting groups of the Crustacea, including forms which are essentially littoral in habit. We have already seen that the porcelain-crabs, the stone-crab, and the masked crab, show striking external resemblances to the true crabs, such as the spider-crabs, the shore crab, and the edible crab, so that a little care is necessary in defining the Brachyura, or short-tailed true crabs, in the narrow sense. That the carapace is usually broad in proportion to its length, and the tail small without tail fan, and reflexed beneath the body in all crabs, it is hardly necessary to repeat. More subtle points are the fact that eyes, antennules, and antennæ, are placed in complete sockets, that the third pair of maxillipedes form flattened plates (opercula) instead of being leg-like, and that the whip (flagellum) of the antennæ is always short. Lest it should seem, however, that this distinction has been made too sharp, it should be carefully noted that in the curious rounded crab *Atelecyclus*, mentioned in the last chapter, the maxillipedes are completely flattened, and meet in the middle as they do in the true crabs. Such facts make the classification of the crabs as difficult as it is interesting, but as we are concerned only with British forms, it is sufficient to regard as true crabs the forms showing the characters mentioned above, *Atelecyclus* being excluded because of the long antennæ.

Of the true crabs we shall consider here only three families, into two of which most of our British forms fall.

The first family is that of the spider-crabs, or triangular crabs, as the Germans call them. There is generally no difficulty in recognising at once the British members of this family. Its scientific name (Oxyrhyncha) refers to the pointed rostrum which forms the anterior angle of the three-cornered carapace. The popular name of "spider" refers to the way in which the small body is suspended on the long spidery legs. Spider-crabs differ, however, very markedly from their terrestrial namesakes in regard to their movements; far from being agile, they rival the historic tortoise in the slowness and deliberation of their methods of progression. Whether the sea-grass grows beneath their feet or not, it is impossible to say; but it certainly does grow freely on their backs, most of them carrying about with them a perfect forest of weeds and sea-firs.

Our largest spider-crab is *Maia squinado*, the great "sea-spider," spiny spider-crab, or devil's crab of the South and West. It is collected in large quantities as an article of food in the South-west, and is also abundant in the Mediterranean, where it was well known to the ancients. The colour is reddish brown, but in life, as in other spider-crabs, the body is usually densely clothed with seaweed and zoophytes, attached by means of numerous bristles. The carapace is ovoid in shape, and prolonged anteriorly into a bifid rostrum with diverging horns. Besides the covering of bristles, its surface is furnished with numerous tubercles, and is strongly spinous at the margins. As in crabs in general, the lowest joint of the stalk of the antenna is firmly fused to the carapace. The abdomen is seven-jointed in both sexes. The carapace may attain a length of eight inches, and then would be about six inches broad, the legs having a span of fifteen inches. If specimens both of this crab and of the stone-crab (*Lithodes maia*, p. 187) can be obtained, it will be found a very useful exercise to contrast the two, noting the superficial points of resemblance, and the real points of contrast. Unfortunately the two are not likely to be both found in the same locality.

The next form is one which is not edible and has therefore no common name. This is unfortunate, because it is in some places extraordinarily common, almost as common as that ubiquitous form which has appropriated the name of "shore crab" *par excellence.* This is *Hyas araneus* (see Fig. 55), the common spider-crab of the East Coast. Abundant as it is, it is not a form often seen except when searched for, and to very many people is known, if known at all, only by the dead specimens flung on the beach after storms. Nevertheless, in the right places one may find a dozen large living specimens in the course of half an hour. What are the right places? is the question naturally asked. Two localities I have always found specially productive. First, deep rocky pools, preferably with overhanging edges densely overgrown with the finer kinds of weed and with zoophytes, whose waters never completely drain away, even at the lowest tide. Secondly, those beds of rounded boulders overgrown with Irish moss and red seaweeds, which are sometimes exposed for a short time at low spring tides. In such places the common spider-crab is generally abundant, but I have never found it so in places where there was not abundant moisture, and a dense growth of red seaweeds, zoophytes, and sponges. Similar growths also cover the back of the crab, and often conceal most of the peculiarities of structure. Your specimens are not likely to live very long in captivity, and while they live are often of more interest on account of the delicate zoophytes they bear on their backs, than because of their own habits, which are chiefly interesting because of their profound leisureliness. When they succumb to the injurious effects of their new surroundings, they may be carefully cleaned and the structure made out.

The process of cleaning is best accomplished by picking off the encrusting weeds bit by bit with forceps. As you do so you will find that they are attached by hooked hairs of remarkable appearance, which cover the surface of the body, and are often very conspicuous in the dried specimens found upon the beach. The hairs are of very considerable interest to those who care about the problems of evolution. Not only are they well adapted for their function of bearing the spider-crab's "forest of Dunsinane," but the crab itself actually attaches weeds and zoophytes to them. When the hairs are removed the carapace will be seen to be covered with the numerous tubercles so characteristic of the spider-crabs in general. It is dull in tint, inclining towards red on the upper surface, young and small specimens being often very distinctly red in colour.

The general points named above having been made out, we may proceed to consider the special characteristics of structure.

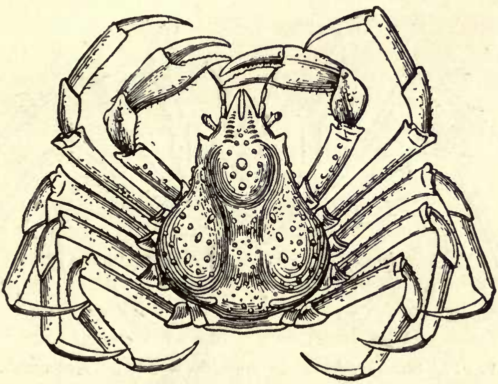

FIG. 55.—*Hyas araneus*, the common spider-crab. The coating of hairs is only indicated.

The carapace is broad, elongated, and triangular, only slightly arched, and prolonged anteriorly into a bifid rostrum, whose converging halves are flattened above and deeply hollowed beneath. Immediately behind the orbit there is a very characteristic spear-shaped process. The abdomen is seven-jointed in both sexes. In large specimens the carapace may have a length of over three inches, and a breadth of over two. In such a specimen the legs would be over five inches long. The specimens ordinarily found on the rocks are, however, likely to be smaller than this.

Besides *Hyas araneus* we have another British species—*H. coarctatus*—which is also very abundant, but occurs in deeper water. It is very much smaller, and is easily recognised by the shape of the carapace. This is suddenly contracted behind the post-orbital processes, so that the regularly triangular shape of *H. araneus* is lost. Young specimens of this species are sometimes to be found far out on the rocks, or among the weed flung ashore after gales, but are difficult to distinguish from the young of *H. araneus*. Indeed, some authorities deny that the two species are distinct.

Related to *Hyas* is the genus *Pisa*, including small, hairy

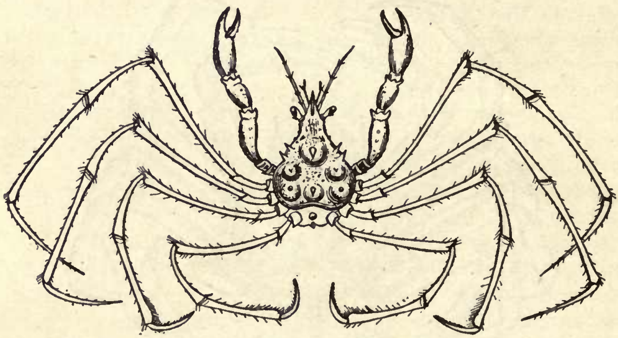

FIG. 56.—*Stenorhynchus phalangium*, the long-legged spider-crab.

crabs, not very dissimilar to *Hyas* in appearance. The two species are too rare in Britain to merit description.

The last two genera of spider-crabs are even more spidery than the preceding, and differ from them in the great length of the walking legs, as contrasted with the short and thick great claws. The great claws are especially thickened in the male.

Under stones at low water there may be occasionally found *Stenorhynchus phalangium* (see Fig 56), a representative of the first genus. The carapace forms an elongated triangle, and is prolonged into a long tapering bifid rostrum. The protruding eyes cannot be retracted into the circular orbits, and are peculiar in bearing on their surface a tuft of bristles. The rostrum is shorter than the stalk of the outer antennæ. The abdomen has six joints in both sexes, the legs are about four times the length of the carapace, are very slender, hairy, and usually covered with weed. Another species occurs in deeper water.

The other genus—*Inachus*—is represented in shallow water by *I. dorhynchus*, found occasionally beneath stones. The carapace differs from that of *Stenorhynchus* in being sub-triangular, nearly as broad as it is long, with short, bifid rostrum. The eyes are retractile, and the orbits elongated, instead of circular. The species is characterised by three spines on the gastric region of the carapace; of these two are anterior and one posterior, the three forming a triangle. There is another species of larger size, but it occurs in deeper water.

The next family of crabs is that of the Cyclometopa, or crabs with rounded forehead. In them the carapace is broad and arched in front and narrows posteriorly; in its whole shape it contrasts markedly with that of the spider-crabs. The common shore crab is an admirable and easily obtainable example of this family, and in it the general characters may be readily observed. Notice how very different is the shape of the carapace from that of the spider-crabs. The rostrum has disappeared, and in its place we have a rounded region between the eyes known as the forehead. From the eyes the margin of the carapace slopes outwards and backwards, and is strongly toothed; this is the antero-lateral margin. Next, the margin slopes inwards and backwards, this region being known as postero-lateral; it is untoothed. Finally, the two postero-lateral borders are united by a line, the posterior margin. It will be noticed that the carapace is here broad in front, where in the spider-crabs it is narrowest, and narrows behind where that of the spider-crab broadens out. Most of our commonest crabs belong to this family, and as these are largely distinguished by the shape and teeth of the carapace, it is worth while being clear as to terminology before beginning the study of the individual crabs.

The Cyclometopa are distinguished from spider-crabs not only in general shape, but by the swiftness of their movements and their high intelligence. Quick at offence and defence, bold in attack, swift in flight, and ingenious in artifice, not many of the arts of war remain unknown to them. Together with the next family, which has but few representatives on our shores, they represent the highest point to which the Crustacea have attained. The high specialisation is seen in many of their structural peculiarities, some of which we have already discussed.

The first member of the family to be considered is the edible crab, *the* crab of the fisher-folk, *Cancer pagurus* of science (see Fig. 8, p. 26). This familiar crab is abundant in all the European seas, inhabiting all depths of water up to about twenty-five fathoms. It is the object of an important fishery, especially in England, where it is more relished than on the Continent. Though always caught on a large scale in crab-pots in the deep water off rocks, specimens of considerable size are nevertheless to be found on the rocks themselves, and are there caught by the fisher children. When exposed by the turning over of the stones under which they lurk, they have a peculiar habit of tucking in the legs under the broad and flattened carapace, so as to offer only its strong surface to the intruder.

The special characters are as follows. The carapace is very broad and only slightly arched, the forehead narrow with three short similar teeth, the long antero-lateral margin is nine-lobed, while the shorter postero-lateral margin is entire and marked by a marginal line. In the great forceps the movable part is black, and furnished on its inner side with blunt rounded projections. The walking legs are all similar, the last ending like the others in a thin pointed claw. For these points see the figure.

The next form is the shore crab (*Carcinus mænas*), to which allusion has already frequently been made. It is abundant everywhere in shallow water, occurs in many colour varieties, and is extraordinarily hardy and successful. A charming pet, it will live long in captivity, even under unfavourable conditions, so long as it is allowed an opportunity of occasionally quitting the water in which it is living, and is well fed.

As to structure, the following points are worth notice. The carapace is broader than it is long, well arched, with three teeth in the projecting forehead, and five in the antero-lateral margin, which is much shorter than the postero-lateral margin. The great forceps are short, the hand has a double keel. The terminal joint of the last pair of walking legs is slightly expanded and flattened. As in the Cyclometopa in general, the abdomen is five-jointed in the male, and seven-jointed in the female. The females will be found not infrequently carrying the bright orange eggs attached to the hairy abdominal appendages.

The next crab is one which is much more likely to be found on the shore after storms than living under natural conditions. This is *Portumnus variegatus*, a peculiar little swimming crab, common off sandy shores, and easily recognised at a glance by the shape of its carapace. This is peculiar in being as broad as it is long, the antero-lateral and postero-lateral margins being rounded instead of meeting at a sharp angle. The last walking leg is, as in the next genus, but to a less extent, converted into a swimming paddle, the terminal joint being broad and flattened, and the penultimate broad, rounded, and compressed. This crab, which has no English name, is a beautiful little creature, of mottled purplish white tint.

Finally, we come to the large genus *Portunus*, including the true swimming crabs, popularly called "fiddlers" from the peculiar motion of the last pair of legs. These appendages are completely converted into swimming paddles, and enable the crabs to dart rapidly through the water, thus taking on the function exercised in ancestral forms by the tail. In general shape the fiddlers resemble the shore crab, the carapace bearing similar teeth on its margin, but it is much flatter and slightly different in its details. The legs, and especially the great claws, are beautifully marked and sculptured, the swimming crabs being alike in colour and form singularly beautiful creatures.

The largest species is the velvet-crab (*Portunus puber*), which owes its name to the dense coat of fine hair which covers the body. It is very rare on the East Coast, but is abundant on the South-west, where it occurs among weeds between tide-marks.

There are numerous other species of swimming crabs, among which may be specially mentioned *P. depurator*, the wrinkled swimming crab, and *P. marmoreus*, a form with beautifully marbled carapace. The species are so numerous that it seems unnecessary here to give their distinguishing features, especially as many of them are very local in their distribution. Swimming crabs are most frequently found on the shore thrown up by the waves, but in certain localities, especially at the edge of rocks running out into the clear sand, it is not uncommon to find them in the living active condition. In the sandy pools the peculiar method of locomotion may then be readily observed. A careful anatomical comparison with *Carcinus* should also be made.

FIG. 57.—*Portunus depurator*, the wrinkled swimming crab. Note the shape of the last pair of legs.

Of the last family of crabs, the Catometopa, or quadrilateral crabs, one example only need be described. This is the very curious *Pinnotheres pisum*, the pea-crab, a very small crab found inside the shells of many bivalves, especially the horse-mussel (*Mytilus modiolus*), the oyster (*Ostrea*), the cockle (*Cardium*), and others. The peculiar habit has given rise to many curious superstitions, the present being one of the first cases known of what we now call "commensalism." The carapace is arched, almost circular, smooth and delicate, and in the female almost uncalcified. The males are smaller than the females, and have a projecting forehead, while that of the females is uniformly rounded.

This concludes our brief survey of the true crabs, which, as we have seen, are the most specialised of the Decapod Crustacea. We have begun our survey of the Crustacea with the Decapods because they are the largest and most conspicuous forms, and because they illustrate so admirably the meaning of the evolution theory. All are constructed on fundamentally the same plan, but display almost infinite modification in detail. As already hinted in the preceding chapters, it is clear that while the ancestral forms, like the more primitive living forms, must have been free-swimming animals inhabiting open water, the tendency of all has been to acquire in many different ways the creeping habit, which is an adaptation to life on the sea-bottom. Further, some forms, like the swimming crabs, have secondarily re-acquired the power of swimming, but accomplish this by the modified legs, and not by the appendages of the tail as the primitive forms do.

The motion of the more primitive swimming Decapods is very well worth study and is of much interest. It is perhaps most easily observed in some of the smaller prawns, which live well in confinement and require less space than the larger forms. When undisturbed their swimming is the perfection of graceful and apparently almost effortless movement. The tail-fan is kept expanded, and serves as a rudder to alter the direction of the movements as occasion may require; it must also be of much use as a float, by its extent and lightness assisting to support the body in the water. The antennal scales, which are often large, no doubt also perform both functions. The propulsion of the body is effected by the movements of the anterior swimmerets, which by their constant motion can drive the body in any direction. Startle your prawn and you will find that it darts backwards or sideways by the sudden flexion of the mobile tail. It is, however, characteristic of the Natantia that their ordinary mode of movement is gentle swimming by means of the anterior five pairs of swimmerets. The creeping Decapods have lost this mode of motion, and though they retain in many cases the power of jerking themselves backward at a sudden alarm, their ordinary method of locomotion is a leisurely creeping. The anterior swimmerets may be retained, or may be largely aborted, but they are never strong enough to propel the heavy body. Beginning with this prime distinction of habit, it is easy to deduce the structural characters of the two sets, and it is of very much interest to note how the minute differences between Crustacea, such as prawn, lobster, and crab, are associated with their differences in habit and mode of life. The intimate nature of the association is often easier to demonstrate in the Crustacea than in other groups, and adds much of their interest to them.

Though the chapters on the Decapod Crustacea have spun themselves out to an unreasonable length, it is not easy to tear ourselves away from so fascinating a group. Two subjects have not yet been spoken of, and must just be touched on.

One of these is the moult, too interesting a phenomenon of Crustacean life to be omitted. We have already dwelt upon the characteristic Crustacean cuticle, or coat, and its advantages as a defence. It has, however, the correlated disadvantage that it periodically becomes too small for its owner, and has to be cast and renewed. This occurs in all Crustacea, but is perhaps best and most frequently seen in the edible crab. If you search diligently under stones far out on the rocks, you will certainly sooner or later come across an edible crab in a sluggish apathetic condition. Watch it, and you will see the whole of the shell split off at the insertion of the legs, and thrown aside, showing beneath it the new coat, very bright in colour but perfectly soft to the touch. Little by little the crab also extricates himself from the rest of his coat, pulling his claws slowly from their envelope, and gradually pushing the discarded shell away from him. Pick this up, and you will find that it is complete in every detail; not only is the covering of every appendage (even the most minute) fully represented, but the covering of the eyes, of the gills, nay, even the lining of the stomach is there. Turn to your soft, helpless crab, and you will see a stranger sight still: the crab which has just come out of the shell you hold in your hand is now bigger, is probably what will seem to you very much bigger than that shell. If, as one is often very apt to do, you have placed the crab when first seen in a bottle for transport, you will find that what went in easily will by no means come out without injury. The meaning of which strange fact is that as the new coat does not stay soft for long, the crab must hasten to get all the growing done possible in the short time at its disposal. But growth is a slow process, so it distends its tissues with water to ensure the new shell being large enough to allow of subsequent growth. Try to boil and eat a "soft" crab, and you will speedily realise the condition of affairs. The process of moulting in a large crab is to be counted as one of the most impressive of the phenomena to be witnessed on the shore, and may often be watched by a close observer. During and after the moult the crab is absolutely helpless, and until the shell grows hard again is at the mercy of every foe. The crab realises clearly its helpless condition, and always seeks shelter in some nook or cranny of the rocks. Even there, however, it is not always safe, and is attacked by members both of its own and other species, who greatly appreciate the succulent morsel. Moulting is in consequence a process full of risk and danger to all Crustacea, but it is the price which has to be paid for the advantage of a coat of armour.

Moulting occurs in all Crustacea, and many times in the life of each individual. The cast coats of the different species are always abundant about the shore rocks, and are often mistaken for dead crabs. They are always interesting and worth study, and can be recommended to those who have scruples about killing animals for dissection purposes.

In still one other respect the Crustacea are of great interest. This is in regard to their development, which is markedly indirect, the young being usually very unlike the adults. Examine a female *Mysis*, or opossum-shrimp (see p. 209), with young in her brood pouch, and you will find that the young are in most respects similar to the parents. This is one of the exceptional cases where the development is direct, and without distinct metamorphosis. It is otherwise with the majority of the Crustacea. In the crabs, for instance, the eggs are carried about by the mother only till they hatch, and the larvæ when hatched (see Fig. 92) are very different from the mother. They are minute, transparent creatures, colourless save for the eyes, with quaintly shaped body furnished with long spines and few appendages. Such embryos are called zoeas, and their relation to the adult crab was for long unknown. The zoea stage of the common shore crab is to be found in vast numbers on the surface of the sea in autumn, but is more likely to be got by tow-netting than in rock pools. The zoea grows and moults and becomes converted into the megalopa, a form much more like a crab than the zoea, but differing markedly from crabs in the presence of a long, mobile abdomen, capable of being used in locomotion. The megalopa is the stage of transition from the free-swimming zoea, whose habitat is the open sea, to the creeping crab, whose habitat is the sea-floor. Its special interest lies in the fact that while the zoea swims by means of its thoracic appendages, as do some of the lower Crustacea, the megalopa can swim with its tail like a long-tailed Decapod. For a full discussion of development of the Crustacea reference must be made to the text-books, but the study of a living megalopa will give you a more real and vivid appreciation of the process than the clearest and best description. The megalopa stage of our common crabs may often be found among weeds in the rock pools.

Fig. 58.—Megalopa of shore crab (*Carcinus*). Note the relative sizes of tail and body, the ten legs, the rostrum between the eyes, and the swimmerets on the tail. After Brook.

When found, place your specimens in a saucer of clean water, and examine with a lens. If you have obtained specimens of different ages you will notice how some move like a *Galathea* by rapid jerks of the tail, how others alternate between this and creeping like a crab, while others, again, confine themselves almost entirely to the latter form of motion. The sight is one which you will probably mark as forming an epoch in your observations of shore animals. The fact in itself is a mere trifle perhaps, but it is one of those apparently trifling pieces of observation which seem to suddenly illumine days of patient, but apparently fruitless, study.

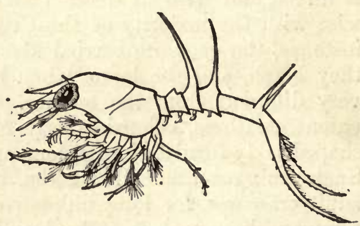

Fig. 59.—Mysis stage of Norway lobster (*Nephrops*). Notice that the biramose legs of the larva are in process of transition into the uniramose legs of the adult. After Sars.

Later the little megalopa tucks in its tail, undergoes certain minor alterations, and becomes converted into the young crab. This is merely one, and by no means one of the most complex, of the life-histories of the Crustacea, but it is one which can generally be easily studied. In Fig. 59 another larval stage, one which is common among long-tailed Decapods, is represented. Its great interest lies in the resemblance to the opossum-shrimp, especially as regards the shape of the legs.

KEY FOR THE IDENTIFICATION OF CRABS DESCRIBED IN THIS CHAPTER.

Order **DECAPODA.**

II. Reptantia (see p. 163), Brachyura, or crabs in the narrow sense, including forms with short antennæ, which, like the eyes and antennules, are placed in sockets.

Carapace triangular with rostrum, legs long .	1. Fam. Oxyrhyncha (spider-crabs).
Carapace broad, arched in front, and narrow posteriorly . .	2. Fam. Cyclometopa.
Carapace usually quadrilateral . . .	3. Fam. Catometopa.

1. Fam. Oxyrhyncha.

Chelipeds not markedly different from other legs .	Rostrum with divergent horns—*Maia* .	*Maia squinado*, with prickly body.
	Rostrum with convergent horns, hollowed beneath—*Hyas* .	In *H. araneus* the carapace is not contracted behind the post-orbital processes. In *H. coarctatus* it is contracted behind these.
Chelipeds much shorter and stouter than other legs, which are very slender	Carapace sub-triangular, nearly as broad as long, orbits elongated—*Inachus* .	Between tide-marks *I. dorhynchus*, with three spines on the gastric region, is the only species found.
	Carapace an elongated triangle with long rostrum—*Stenorhynchus* . .	Between tide-marks occurs *S. phalangium*, in which the rostrum is shorter than the stalk of the antennæ.

2. Fam. Cyclometopa.

- *a.* Walking legs all with thin pointed terminal segments — Carapace with nine lobes—*Cancer pagurus*, or edible crab.
- *b.* Last pair of walking legs with expanded fin-like ending.
  - Carapace as long as broad—*Portumnus* — *P. variegatus* is only species.
  - Carapace broader than long
    - Last segment of fifth legs only expanded — *Carcinus* . — Only species is *C. mœnas.*
    - Penultimate segment expanded as well as last —*Portunus* . — Many species, *e.g.* *P. puber*, *P. marmoreus*, etc.

3. Fam. Catometopa.

Carapace incompletely calcified. Habitat within bivalves . — *Pinnotheres pisum.*

SUMMARY CLASSIFICATION OF DECAPOD CRUSTACEA.

I. Natantia—swimming forms with compressed bodies and functional swimmerets; *e.g.* prawns and shrimps (Chap. VIII.). Fam. Carididæ.

II. Reptantia—creeping forms, sometimes with long tails (Macrura), *e.g.* lobster and crayfish; sometimes with inturned tails (Brachyura), *e.g.* crabs; intermediate forms also occur. The following families are included :—

(1) Astacidæ, lobster and Norway lobster.
(2) Palinuridæ, rock-lobster.
(3) Porcellanidæ, the lobster-like Galatheas and the crab-like porcelain-crabs.
(4) Paguridæ, the hermit-crabs.
(5) Lithodidæ, the stone-crab, with large incompletely calcified abdomen.
(6) Corystidæ, the masked crab and the circular crab; the latter is sometimes placed in the family Cyclometopa.
(7) Oxyrhyncha, the spider-crabs, apt to be confused with the stone-crab.
(8) Cyclometopa, the shore crab, swimming crabs, and edible crab.
(9) Catometopa, the pea-crab, and a few other southern forms.

NOTE ON DISTRIBUTION.

Generally speaking it may be said that the crabs increase in number in the British area as one passes southward. Exceptions to this rule are the interesting stone-crab, a northern species, and the two species of *Hyas*. These last are not absent from the South-west of England, but they are not nearly so abundant there as in the North. On the other hand, the rocky coasts of Devon and Cornwall produce *Maia squinado*, especially abundant in Cornwall, the velvet-crab between tide-marks, and a number of other interesting and peculiar forms of which no mention has been made here. The shore crab, the edible crab, the numerous species of *Portunus* apart from the velvet-crab, occur at all parts of the coast.

CHAPTER XI.

SOME OTHER CRUSTACEA.

The opossum-shrimp and its allies—Sessile-eyed Crustacea—Structure of Isopods—The Amphipoda—Characters and habits of sand-hoppers—Structure of Caprella—The lower Crustacea—Structure and habits of acorn-shells and barnacles—Crustacean parasites—Sea-spiders—Their zoological interest.

WHILE searching for shrimps and prawns, you are certain sooner or later to encounter some little shrimp-like creatures of singularly beautiful appearance. Far out on the rocks, in clear pools floored with silver sand, you will find them swimming with outspread eyes, and bodies of crystal clearness. Turn to the shallower pools lined with green weed and you will find similar forms, but here of the same pale green as their surroundings. Again, if you push aside the great blades of Laminaria, you will see darting out from beneath them in shoals the same little creatures, but now of a deep brown tint. This is *Mysis flexuosa*, sometimes called *chamæleon* from its Protean tints, and chamæleon-like in its power of colour change. Swift swimmers as they are, they are easily caught, and, though difficult to keep in an aquarium, they are well worth study. Collect a good handful, and put them with plenty of clean water in a glass jar. You will then have no difficulty in seeing that in many respects they resemble shrimps and prawns very

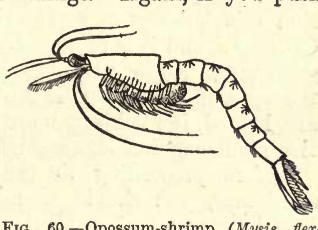

FIG. 60.—Opossum-shrimp (*Mysis flexuosa*). Female specimen, showing brood pouch between the posterior legs.

closely (Fig. 60). Like them they have an anterior region, not obviously segmented and covered by a shield; a tail region divided into segments and ending in a powerful tail fin, and long feelers colourless in the living animal, and bearing a large scale or squame at their bases. They differ from shrimps, however, in that they seem to have far more legs, and in that many of them have a pouch attached to the posterior legs, as is shown in the accompanying figure. These are the females, and when adult the pouch will be found to contain developing eggs. The eggs are placed in the pouch when laid, and are carried about by the mother. The members of the order to which *Mysis* belongs are all very good swimmers, well adapted for life out in the open sea, but, as happens with so many marine animals, the females come inshore at the breeding season. This is partly, no doubt, for the sake of the young when hatched, but probably, in other cases, because the weight of the eggs or young must greatly diminish the swimming power of the mother. Your specimens are almost certain to be all females, and a very brief experience will be sufficient to teach you that the large mature specimens are so sensitive to unfavourable conditions, that they will not readily live in confinement. In a very short time they lose their lovely tints, become dull and opaque, and drop to the bottom of the jar. You will find that this delicacy of egg-carrying females is common in the Crustacea, and it is profoundly interesting, for it shows how great must be the advantage of the habit of carrying about the eggs, if it can persist against such heavy odds. There are, indeed, few subjects more interesting than the reproductive phenomena of shore animals.

Before proceeding to the examination of your dead specimens, you should examine the living ones under a lens in a watch-glass filled with sea-water. Whatever be the prevailing tint, and it varies much, you will find the dorsal surface covered with the same beautiful branched pigment cells seen in the shrimp. They are here black in colour and are often arranged segmentally, one for each segment. This is indicated in the figure. The rest of the body may be green, or brown, or transparent, but the anterior region is almost always delicately suffused with pink, especially about the antennæ. You will notice also the large, very movable eyes, usually outspread laterally, but capable of much freedom of movement. Also the curious bend in the middle of the body, which gives rise to the name *flexuosa*, and has at times almost the look of a deformity. The larger specimens will be found to be over an inch in length, but many are much smaller. With the lens there is no difficulty in making out that there are eight pairs of legs, very similar to one another, and that all of them consist of two branches. It is on account of this and of some other characters that *Mysis* is included in the order Schizopoda, or "split-footed," as contrasted with the Decapoda, or Crustacea with ten legs, already described. The Schizopods are even more purely swimmers than the Natantia among Decapods; they have no walking legs, strictly speaking, and their eight pairs of thoracic legs resemble one another very closely.

The *Mysis* described above is by far the commonest member of its order on the shore, for the great majority of its relatives live in the open sea, but there are a few other nearly related forms which occur more sparingly along with *Mysis flexuosa*, or are occasionally found far out at exceptionally low tides. All these belong to the family Mysidæ, and resemble one another so closely that their discrimination requires some care. Those who are fond of species work will find Mysidæ peculiarly fascinating, while others are recommended to rest content with *Mysis flexuosa*. We shall describe one or two representative species only.

To begin with the large *Mysis flexuosa*. We have already seen that it belongs to the order Schizopoda; it further belongs to the family Mysidæ because of the following characters. Its eight pairs of thoracic limbs are similar but not identical, for the first two have a masticatory process at their base, and the first has also a flat vibratile appendage. Some of the posterior thoracic limbs bear somewhat similar appendages, which here, however, are apposed so as to form the brood pouch in the female. Gills are entirely absent. There is much difference between the sexes, especially as regards the abdominal appendages, for these, except the last pair, are well developed in the male and rudimentary in the female. The inner branches of the tail fins bear round auditory organs (*o* in Fig. 61), for *Mysis* has ears in its tail. The last five segments of the thorax are more or less movable, not fused together as in shrimps. All the Schizopods you are likely to find on the shore belong to this family. It is divided into a great number of sub-families, chiefly on account of the varying structure of antennæ and telson, and the sub-families contain numerous genera, but it will be sufficient for our purpose to retain the genus *Mysis* in its old sense. For further details reference should be made to Canon Norman's papers (see books of reference at end).

If you have succeeded in laying out the thoracic limbs

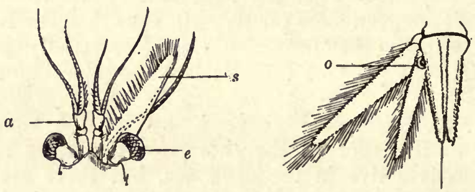

Fig. 61.—*A*, head, and *B*, part of tail of *Mysis*. *A* shows the eyes (*e*), the scale (*s*), and part of the flagellum of the right antenna, and the two antennules (*a*). *B* shows the telson (*t*) and the left terminal swimmeret, with the ear (*o*) in the inner branch. After Bell.

of *Mysis flexuosa* in a row, and demonstrating the other characters of the family to your satisfaction, you will find no further difficulty in studying its specific characters. Besides the points already noted it is distinguished by the following peculiarities. First, the length of the antennal scale (*s* in Fig. 61). To see this clearly, float your dead *Mysis* in water—the lid of a white ointment jar makes a good dissecting dish—and observe under a lens. You will then see clearly the antennæ with their long flagella and stout scales (*s*), and the shorter antennules (*a*), each with a three-pointed stalk and two feelers. In *Mysis flexuosa* you will find that the scale of the antennæ is narrow and very long, twice as long as the stalk of the antennules; it is without bristles (setæ) on its outer margin, and that margin terminates in a distinct spine; all these points are clearly shown in Fig. 61, *A*, which also shows the eyes (*e*).

Turn now to the telson, or last segment of the body, and you will find that this is deeply cleft at its tip (*t* in Fig. 61), and bears twenty-one to twenty-seven spines on either side. Note at the same time the curious ear (*o*) in the swimmeret. Minute points of no importance you will probably think these, but your respect for them will probably increase when you examine specimen after specimen and find them constant, true indices of those subtle undefinable characters which make up the species *M. flexuosa.* There are few more striking illustrations of what is meant by the constancy of nature, than the characters of nearly related species like those of the genus *Mysis.* In many cases the species is defined by the relative size of two structures, or by the number of spines borne by an organ. What invisible force is it that limits the growth of the antennal scale in *M. flexuosa* when it is twice as long as the stalk of the antennule, and allows that of *M. vulgaris* to grow till it is four times as long? Why should the latter never have more than twenty-five spines on its telson when the former may have twenty-seven? When these and similar questions crowd upon you, then the fascinations of species work will become clear. One would not of course deny the existence of variability here, as elsewhere, but very little species work will serve to convince you of the essential constancy upon which the variability is superimposed.

The characters given above will be found sufficient to identify *M. flexuosa.* Another species, smaller in size and much less common, may be sometimes found with it. This is *M. vulgaris*, which, though occasionally found in rock pools, is typically an inhabitant of tidal rivers and estuaries. It is most likely to be found in the pools left by the ebbing tide on those mud flats which in Northumberland are called "slakes"; or sometimes occurs in myriads at the edges of tidal rivers. This species may be recognised by the fact that the antennal scale has no spine, is furnished with setæ all round, and is four times as long as the peduncle of the antennules. The telson is not cleft, and ends in four spines.

There are a great many other species of *Mysis* found more or less commonly on our shores, but for these reference must be made to Canon Norman's papers. I shall mention one more only, which I have found to be not infrequent on the East Coast, and which is interesting on account of its colour. This is *Mysis lamornæ*, a delicate little creature not much more than one-third of an inch long, and wholly or partially of a bright red colour. It is often in large part perfectly transparent, but is suffused with scarlet and bears bright scarlet eggs. It may be found under stones far out on the rocks, and may be recognised by the very large eyes borne on short stalks, and by the fact that the antennal scale is the same length as the peduncle of the antennule, and that the telson is cleft for one-quarter of its length, without spines in its upper portion, and furnished distally with six to twelve at either side. The distribution of this species in Europe is wide, for it ranges from Lofoten, on the coast of Norway, through the Mediterranean to the Black Sea. The colour is also worth notice, for bright red is common in deep-sea Crustacea and in pelagic forms, but is rare in those found near the shore.

In the above species the specimens found are much more likely to be females than males. When found the males may be recognised by the absence of the brood pouch, the slimmer form, and the nature of the swimmerets. The third and fourth of these are much better developed than in the females, the fourth being furnished with a long many-jointed whip-like structure.

We shall not here describe any other of the British species of *Mysis*, but a not uncommon form which is now referred to another genus is worth notice. This is *Siriella armata*, found in rock pools in company with *Mysis flexuosa*, but distinguished by its smaller size and more delicate appearance. It is referred to a different genus because the outer branch of the last swimmerets is divided into two joints, the carapace is prolonged anteriorly into a long rostrum instead of ending in a blunt point, and all the swimmerets of the male except the first are well developed, some of them being furnished with a curiously coiled process. In the species named the rostrum is as long as the antennal scale, both being slightly shorter than the stalk of the antennules. The telson is very long, not cleft, slightly constricted at its base, its margin being furnished with a few short spines placed between longer ones. This species is difficult to distinguish from other closely related species of the genus, but it will be found that the telson ends in four minute spines, separated by two setæ from the large lateral spines.

The above may serve as examples of our British Mysidæ, and will show how relatively small are the differences which separate the species and even the genera, compared with the differences between the sexes. When to this is added the fact that many of them only appear sporadically and locally on our coasts, it will be readily understood that not only have males and females been commonly referred to different genera, but also that the different specialists in the group have held very various views as to what should constitute generic or specific distinctness. Consequently there is great confusion as to the names of the different forms. For example, a form described in Bell's Crustacea under the name of *Themisto brevispinosa* appears to be only the male of *Mysis flexuosa*.

The other Schizopods lie somewhat outside our range, for they inhabit the open sea. The interest of the order as a whole lies in the general resemblance to the Natant Decapods, and the detailed similarity to the larvæ of many of the Decapods (see Fig. 59). The beauty of the form and colour, the activity, the frequent extraordinary abundance of individuals, and the habit of swimming in shoals should also be noticed.

The orders Decapoda and Schizopoda, whatever their other differences, both include forms having stalked eyes and a dorsal shield or shell, but there are other shore Crustacea of considerable size and complexity in which the eyes are sessile and the dorsal shield is absent. These fall into two sets: (1) the Isopoda, forms more or less like the common "slater," or wood-louse, with flattened bodies, and (2) the Amphipoda, or sand-hoppers, whose bodies are compressed, and who usually have six abdominal legs, three directed forwards and three backwards. We shall not enter into either of these orders in detail, for their members are not as a rule attractive to most people, and are often difficult of identification.

As an example of the Isopoda we may take a not uncommon and somewhat interesting form known as *Idotea tricuspidata*. It is usually found clinging to weed, especially

Fucus, by its numerous sharp-clawed legs, and is extraordinarily variable in colour. Usually brown or brownish, it is sometimes tinted with yellow, red, or green, sometimes spotted or striped with darker colour. The length varies from three-quarters of an inch to an inch or more, and the flattened body makes the little creature very inconspicuous.

As in other members of the order, the number of rings in the body is primarily the same as in Decapoda, but the body is distinctly divided into three regions, of which the thoracic is the most conspicuous. The first thoracic segment is fused to the head, so that the thorax appears only to possess seven rings; the abdominal segments are in part fused. The head bears two pairs of antennæ, consisting of simple flagella; of these the outer are half as long as the body. There are seven pairs of similar thoracic legs, corresponding to the seven free thoracic segments. Over the surface of the abdomen there is a triangular tail-shield which covers all except the two first rings. The five anterior abdominal appendages are converted into thin respiratory plates, the sixth pair forms two strong valves which cover over these thin plates. In life the valves are in constant motion, opening and shutting to facilitate the passage of water over these curious breathing organs, which replace the gills of the Decapods. A careful dissection of *Idotea* is easily made, and will be found very profitable.

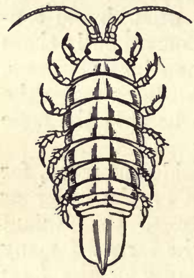

FIG. 62.—*Idotea tricuspidata*. In part from Bate and Westwood.

The Amphipoda are most typically represented by the sand-hoppers, which swarm everywhere over the damp sand, assembling in myriads about decaying substances thrown on the beach, and perforating the dry sand above high-tide mark in all directions with their burrows. They are the great scavengers of the shore, sometimes within a few hours reducing dead birds of considerable size to the condition of skeletons. On the rocks their place is taken by other forms equally abundant, and of similar habit.

The common sand-hopper is *Talitrus saltator*. Like its allies, it presents a general resemblance to the Isopods, but differs in the compressed shape, and in the fact that the thoracic appendages bear breathing organs, while the abdominal are used for swimming and jumping. As special characters are to be noticed the absence of the anterior antennæ (antennules), and the great length of the posterior. Of the seven thoracic legs the first pair are larger than the second. The first three abdominal appendages are turned forwards, and are used for swimming; the last three are turned backwards, and are used for jumping. The colour, as everyone knows, is a peculiarly glassy yellowish white, or occasionally a dark dirty tint.

Under stones in the rock pools the true sand-hopper is replaced by swarms of another little creature of similar size. This is *Gammarus locusta* (see Fig. 63), the great scavenger of the rock pools, as the sand-hopper is of the shore. It is easily distinguished from the latter by the fact that the anterior antennæ (antennules) are well developed, and have two filaments each. When suddenly uncovered by the removal of the stone under which it has been lying, *Gammarus* exhibits a curious sidelong movement, which seems to combine the maximum effort with the minimum result. If you shake out a bunch of weed in water, however, you will find that the little animals can swim swiftly enough.

FIG. 63.—*Gammarus locusta.* Note the two pairs of feelers and the number of legs, of which there are seven pairs belonging to the thorax.

Another somewhat interesting shore Amphipod is *Amphithoë podoceroides*, which makes nests of weeds under stones. The nests are often of considerable length, and very neatly woven, and are a source of much disappointment to many a young shore naturalist. The nest is found with joy, and torn open by careful fingers, eagerly expectant of a prize, when instead out shoots the *Amphithoë*, or oftener, perhaps, two of them, male and female together. Why they should be a disappointment perhaps is not obvious, but it is an undoubted fact that most people cannot carry their enthusiasm as far as Amphipods. The species named reaches a length of about three-quarters of an inch, and is usually olive-green in colour, minutely speckled with black spots. The inferior antennæ, or antennæ proper, are shorter and stouter than the superior, and the last pair of jumping legs are furnished with hooks.

Before leaving the Amphipods one other set of forms must be noticed. These, typically represented by the species of *Caprella*, are very different from the rest, being both curious and beautiful, but unfortunately not very abundant or very easy to find. Study closely a rock pool lined with red seaweed, and you may see a slender thread-like creature, probably rather over half an inch in length, which attaches itself to the weed by its long back legs, and sways back and forwards in the water. The tint is exactly that of the weed, and the swaying motion so similar to that produced by currents of water, that it is exceedingly difficult to distinguish the little organism. Disturb it, and it will swim rapidly through the water by suddenly contracting and straightening the body, or travel over the surface of the weed by alternately fixing the opposite ends of the body like a "looping caterpillar." It is unfortunate that we have no common English name for these interesting and curious little creatures. One or two should be taken home for careful examination under a lens. It will then be found that the second thoracic segment is fused to the head as well as the first, so that there are only six free segments. In the figure the first and sixth are numbered. The abdomen (*ab*) is greatly reduced, and at most bears mere rudiments of appendages. The head bears two pairs of similar antennæ, and on account of the fusion of segments the first pair of legs appears to arise from it. The second pair of legs is large and sub-chelate, as in some shrimps—that is, the last segment can be bent down on the second

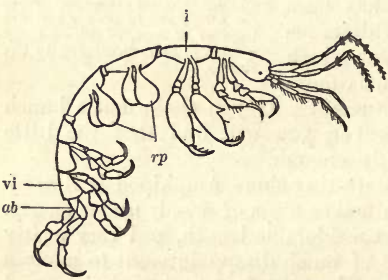

FIG. 64.—*Caprella linearis.* The letters are explained in the text.

last, to form a kind of forceps. There are no true appendages on the next two segments, but merely two expanded respiratory plates (*rp*). In the mature female these segments also give rise to four incurved lamellæ, which together form a brood pouch containing the transparent eggs. The last three thoracic segments each bear a pair of well-developed legs directed backwards. The abdomen (*ab*) is reduced to a mere knob. There are several species which are not very easy to distinguish from one another; the commonest is, perhaps, *Caprella tuberculata.*

We have given very few examples of these sessile-eyed Crustacea, because they are not of great general interest, and those who are desirous of pursuing the subject further will find Bate and Westwood's *British Sessile-eyed Crustacea* a comprehensive and readily accessible work.

The Amphipods and Isopods do not complete the Crustacea, for there are in addition a considerable number of other orders, all comprised in the Entomostraca or lower Crustacea, as contrasted with Amphipods, Isopods, Schizopods, and Decapods, which are all included in the Malacostraca or higher Crustacea. The Entomostraca are usually of small size, consist of a variable number of segments, and have no gizzard or gastric mill. A large number of them are parasites, often very degraded parasites, and many others are water fleas, such as may be found in any pool. The latter form an important part of the food of fishes and other marine animals, but cannot be considered in detail here. Of the Entomostraca we shall consider only four common examples, all belonging to the order Cirripedia.

Our first example is, perhaps, the most abundant animal of all on many shores. This is *Balanus balanoides*, the common acorn-shell, often so abundant as to whiten the shore rocks, and also covering shells, posts, and almost every available surface within tide-marks. At low tide the little white cones look dead and desolate enough; but if you watch a mass of them exposed to the action of the incoming water, you will find the scene changed indeed. As the white water breaks foaming over the rock, and trickles off more slowly, you will see each tiny shell open and protrude a delicate fringe, which opens and closes in frantic haste as if its owner were aware that the water would soon be gone.

There are few more beautiful sights than a rock covered with acorn-shells exposed to dashing breakers. The moist oxygenated air seems to excite the little creatures, and they open almost before the first drops touch them, and keep up their vigorous fishing till the last drop trickles off the rock. The sight of those myriads of little fans in action is one not soon to be forgotten. The acorn-shells have another interest in their history. They were long thought to be molluscs, and it was not till, in 1830, their development was fully worked out by J. Vaughan Thompson, that their true position was understood.

The details of the anatomy are somewhat beyond our scope, but we may notice that the segmentation of the body is quite indistinct, and that it is clothed in a fold of skin, which secretes a shell of limy plates. The limy plates consist of a ring fixed to the rock and inclosing the body, and a movable lid or operculum, formed of separate plates, which open to allow the protrusion of the six pairs of two-branched jointed feet. The commonest species is *Balanus balanoides*, but there are several others on our shores.

An even more curious creature is the related ship-barnacle, *Lepas anatifera*, occasionally found on wreckage on the shore. It has a long fleshy stalk, usually several inches in length, bearing at its tip a complicated whitish shell, and attached to floating wood by the other end. The shell is formed of five separate plates, and in life is continually opening at its tip to allow the six pairs of jointed legs to be protruded. The ship-barnacle has some antiquarian interest, because it was thought by the old authors to have some connection with the Bernicle Goose. The old herbalist Gerard described the young geese hatching out of the barnacles under the influence of sunlight, but though there are very many strange things about these curious creatures there is nothing quite so strange as this.

Two more of the lower Crustacea must be briefly described, not because they can be studied with any degree of success, but because they are certain to be encountered. These are two parasites, which are true Crustacea in their youth, but in adult life display no trace of Crustacean characters. One, *Peltogaster paguri*, is very common on the hermit-crab, the other, *Sacculina carcini*, is found on the abdomen of the shore crab, or occasionally on the swimming-crabs. If you keep hermit-crabs even for a short period in a crowded collecting-bottle, they very speedily show their discomfort by quitting their shells. As they trail the lank abdomen behind them, you will notice in one or two cases a large rounded cylindrical body of yellowish colour attached to its under surface. This is the parasite, and its only distinct structural peculiarity is the reproductive orifice at the broader end of the cylinder. Dissect a dead hermit, and you will find ramifying through its abdomen a system of fine roots, by means of which the parasite feeds itself. It has no mouth, no alimentary canal, no appendages, and is chiefly a mere sac of eggs. Much less conspicuous is the rounded *Sacculina* on the abdomen of crabs, for it is partly concealed by the inturned tail of the crab. Its structure is similar, except that the reproductive orifice is in the middle instead of at one end.

One other small group may be considered here in connection with the Crustacea, for though its littoral members are few in number, they are very common, and the group itself is one of great interest. This is the Pycnogonida, or sea-spiders, including small long-legged, spidery creatures common under stones on the shore. Two are very common; one (*Pycnogonum littorale*, see Fig. 65) occurs under slightly muddy stones, and is a dirty yellowish flattened creature with four pairs of stout knobbed legs, and a massive trunk prolonged forwards into a large cone-shaped proboscis, and bearing four brownish eyes on its dorsal surface. It is the most sluggish and leisurely of creatures, moving, when it does move, by slowly lifting one after the other its eight clawed legs. The other common form is more attractive both in tint and in shape. It is bright pink in colour, with long slender legs about three times the length of the body, and ending in long claws. In addition to the eight legs which it possesses in common with the preceding, it has a pair of short chelate appendages about the mouth, while the male, as in the preceding form, has two very

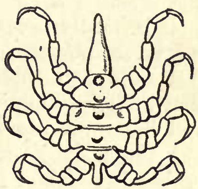

FIG. 65.—Sea-spider (*Pycnogonum littorale*).

slender appendages used for carrying the eggs. This pretty little creature rejoices in the dreadful name of *Phoxichilidium femoratum*, and is to be found not uncommonly under stones or clambering over weeds between tide-marks.

Other forms often occur in numbers on weeds cast ashore by storms. These are species of *Nymphon*, white or pinkish in colour, and not unlike the last in appearance, but with even more slender filiform legs, three or four times as long as the body. They differ from the preceding in having, in both sexes, three appendages in front of the first pair of legs. Beside the mouth, as in *Phoxichilidium*, are two small chelate limbs, behind these two pairs of slender appendages, the first with four or five joints, the second with nine. The first two pairs of appendages are used in connection with food catching; the third in the male, as in other Pycnogonids, carries the eggs, while in the female they are functionless. The remaining four pairs function as organs of locomotion in both sexes. This is the typical condition of the appendages, from which the common *Pycnogonum littorale* diverges widely.

It is hardly necessary for us here to consider in detail the special characters of these curious creatures, but we may just note that their interest lies in great part in the fact that their systematic position is very uncertain. The body and limbs are segmented; they are undoubted Arthropods, but the body is divided into three regions—unsegmented proboscis, trunk of four segments, and unsegmented abdomen,—and there are no antennæ or gills; a connection with the Crustacea is therefore not obvious. Of terrestrial Arthropods spiders seem to resemble them most in the absence of antennæ and the presence of four pairs of legs, but spiders have two appendages only in front of the first walking leg, and sea-spiders may, as we have seen, possess three. Their position is thus wholly doubtful, and the question of their relationships unsolved.

One other point of interest is found in the fact that, as in the sea-horse among fishes, it is the male and not the female which carries about the unhatched eggs. In the Crustacea it is of course the females alone which do this. Insignificant as the sluggish sea-spiders may seem to be, they are thus not without points of interest. Nor are they always small, for a magnificent form of large size occurs in the Arctic Ocean, and with the Gorgon-headed starfish (*Asterophyton*) and some other beautiful creatures, rewards the zeal of the investigator of that chilly sea.

KEY FOR IDENTIFICATION OF MYSIDÆ.

Order **SCHIZOPODA.** Crustacea with eight similar pairs of biramose thoracic legs.

Fam. MYSIDÆ. Gills are absent. Auditory organ present in the tail.

Outer branch of uropods one-jointed, and furnished with bristles on its outer margin . .	*Mysis* .	Antennal scale twice as long as peduncle of antennæ. Telson cleft—*M. flexuosa.*
		Antennal scale three or four times as long as peduncle. Telson entire—*M. vulgaris.*
		Antennal scale same length as peduncle. Telson short, cleft for one-quarter its length, upper half without spines—*M. lamornæ.*
Outer branch of uropods two-jointed, first joint with spines, but not bristles, on its outer margin . . .	*Siriella*	Antennal scale same length as rostrum—*S. armata.*

OUTLINE CLASSIFICATION OF LITTORAL CRUSTACEA.

Sub-class **MALACOSTRACA.** Body with nineteen segments.

Section A. Forms with stalked eyes.

Order 1. DECAPODA (see p. 208).

Order 2. SCHIZOPODA. Eight pairs of similar biramose feet.

Fam. MYSIDÆ. Auditory organ in tail.

Section B. Forms with sessile eyes.

Order 1. ISOPODA. Body flattened, appendages of abdomen, respiratory plates.

Only one form, *Idotea tricuspidata*, has been described in the text.

Order 2. AMPHIPODA. Body compressed, abdomen usually with six pairs of legs.

In the text three sandhopper-like forms have been described, as well as a member of the family Caprellidæ, in which the abdomen is greatly reduced.

Sub-class **ENTOMOSTRACA.** Body usually with few segments.

Order CIRRIPEDIA, including parasitic (*Sacculina*), and degenerate sedentary forms (*Balanus*).

There are very many other kinds of Crustacea, especially of Entomostraca, not alluded to in the previous chapters on account of their small size, or rarity, or absence from the shore.

PYCNOGONIDA, OR SEA-SPIDERS.

A small group of uncertain affinities. Four pairs of walking legs, abdomen rudimentary, without appendages.

No other appendages except four pairs of legs in female, male with slender egg-bearing legs . .	Legs stout and relatively short—*Pycnogonum* .	Colour yellowish white—*P. littorale.*
Chelipeds present near mouth, in female no other appendages except the legs, in male egg-bearing legs as before .	Legs very slender and long—*Phoxichilidium* . .	Legs about three times as long as body. Colour pink—*P. femoratum.*
Chelipeds and two other pairs of appendages near mouth in both sexes . .	Legs very long and slender—*Nymphon* . . .	The species are not very well defined.

CHAPTER XII.

MOLLUSCS, OR SHELL-FISH.

General characters of the Mollusca—An outline classification—The Chitons, their habits and structure—The common limpets—Forms with coiled shells—Their general characters—Tops and periwinkles—Species of periwinkles—Some allied forms—Carnivorous forms—Whelks, purples, and their allies—Their egg-capsules and development—The cowry.

THE Mollusca form a very large group, including animals which are usually well defined and easy to recognise. The fact that most possess a shell which is easy to study and to preserve has rendered them general favourites among those interested in shore animals. Probably, indeed, most people have at some period of their lives made collections of shells; all know how beautiful in form and colour they often are. Interesting as shells are, however, it cannot be denied that as a whole the Mollusca are a group of considerable difficulty. The shells are much more external structures than the coats of the Crustacea, have a less intimate connection with the body, and are therefore not of much use as guides to affinities, except to a very general degree, while the study of the internal structure is not easy. It is a natural result of this, that while much has been written on the shells of Mollusca, their internal structure is still in many cases insufficiently known.

Perhaps the easiest way to get a general notion of the structure of Molluscs is to begin with the study of some of the limpets. Knock off the rocks a few large specimens of the common limpet, and look for the largest specimen you can find of the little tortoise-shell limpet, or its relative the little pink limpet, to be found far out on the rocks among the great blades of *Laminaria.* Put your specimens in a glass jar filled with clean water, and examine the lower surface (see Fig. 66). Some of the points of structure we have already noticed: the muscular foot in the centre, used here, as in many Molluscs, as a creeping surface; the head, separated from the foot by a constriction, and bearing mouth, horns or tentacles, and eyes; the mantle-fringe, or flap, hanging down at the sides of the body like a frill, and secreting the conical shell above. In the tortoise-shell, but not in the common limpet, there is a single plume, or gill, exserted when the animal walks. These points studied, drop your specimens for a few minutes into hot water or spirit, and then remove the shells by slipping a sharp-pointed knife round the sides of the animal. Detailed dissection is not easy, but some points can be readily made out. Notice that the mantle is arched in the head region, so that it there forms the roof of a small chamber—the mantle-cavity, which in the tortoise-shell limpet contains the gill. The mantle-cavity is a very important structure, and you should take pains to assure yourself that it is outside the body-cavity, that it is equivalent to the gill-chamber of the Crustacea, and is formed by the downgrowth of the mantle-flap, a free fold of skin. One other structure is of great importance; this is the so-called tongue, or radula, a long, brownish thread, much longer than the animal, which lies folded up at the right side, and is very easily found. When examined with the lens it will be found to be covered with numerous rows of small teeth. By means of it the limpets mow down the sea-grass upon which they feed, but the carnivorous Molluscs use it as a drill to perforate the shell of other Molluscs.

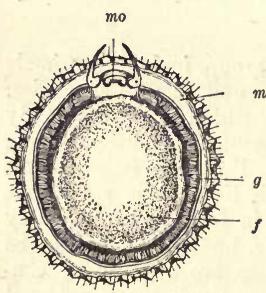

FIG. 66.—Under surface of common limpet (*Patella vulgata*). *mo*, mouth; *ma*, mantle prolonged into fine processes; *f*, foot; *g*, respiratory region of mantle.

One other point must be noticed in regard to the anatomy of the limpet. The posterior opening of the food canal, instead of being at the end of the body, as one would naturally expect, is close to the head at the right side—that is, the limpet is unsymmetrical, the organs being, as it were, twisted round to the right side.

The division of the Molluscs to which the limpets belong is known as the Gasteropods. Gasteropods are usually characterised by the presence of a shell, sometimes conical, usually coiled, but at times absent. The mantle-fold is single, and overarches a cavity which usually contains a single gill; but, as in *Patella*, this gill may be absent, when its function is taken on by the mantle-fold. The foot forms a flat surface used for creeping; the head is distinct, bears tentacles and eyes, and within the mouth there is almost invariably a well-developed radula. The body is usually markedly unsymmetrical, but where the shell is absent it may exhibit an apparent symmetry. There are an extraordinary number of Gasteropods, living on land, in fresh water, and in the sea, the most familiar forms being those with coiled shells, such as whelks, periwinkles, snails, and so on.

Contrasted in many respects with the Gasteropods are the Bivalves, or Lamellibranchs, such as oysters, clams, mussels, cockles, etc. One may think of them in relation to Gasteropods in this way. Suppose in a limpet the body were to be greatly compressed laterally, the simple conical shell, one might suppose, would yield to the pressure so as to divide into two valves united by a hinge; the foot would lose its creeping surface and become narrow and compressed, the mantle-flap would grow downwards at each side, and, in conformity with the two-valved shell, would become double instead of single. If we suppose that at the same time the separate head, the tentacles, the eyes, and the radula were to be lost, symmetry to be acquired, and a second gill to appear, we should have roughly indicated the chief points of difference between Gasteropod and Lamellibranch. The latter are much more sedentary than the former, which usually live buried in sand or mud, and show fewer variations in structure. All feed on microscopic food particles in the water, and have large flat *plate-like gills*, whence the name of *Lamellibranch*, and have a double shell, whence the alternative name of Bivalve.

The third great set of Mollusca includes the active predaceous cuttles, which are known as Cephalopoda. In them the foot has grown up round the mouth, and is split up into "arms" furnished with suckers. Except in the pearly nautilus of the Pacific, there is no external shell, and the structure is in many respects strangely modified. Most of the cuttles live in the open sea, and they are not common on the shore rocks.

In studying the Mollusca we shall first consider the Gasteropods, beginning with some old-fashioned forms, which are sometimes separated from the Gasteropods, because they are in many respects of simpler structure. These are the species of *Chiton*, animals very common on our coasts, and known as fossils from very early rocks. So abundant are the Chitons on the shore rocks, that one species at least can always be found even at the most sluggish of neap tides. They live on and under stones, and are of small size, being usually not more than about half an inch in length, and often less. The shape (see Fig. 67) is a long oval, and the most marked characteristic in surface view is the presence of no less than eight overlapping shell-plates, embedded in a tough roughened mantle, which projects at the margin of the plates. Remove the animals from the rocks with your fingers, and you will find that they immediately begin to curl up, bending the body at the junctions of the plates. Watch living specimens crawl over the muddy shale, and notice the slug-like movement, and the muddy track left on the rock. Induce your specimens to crawl up the side of a clear glass vessel, and study the under surface. In the centre lies the foot, a muscular creeping surface, as in limpet or snail. In front of it, and not clearly separated from it, is the head, without tentacles or eyes, but with a very distinct mouth-opening. By watching closely you may see a brown ribbon protruded from this opening, and used to scrape off the glass the small green Algæ which soon grow in aquaria; thus *Chiton* has a radula in its mouth just as the limpet has. At the sides of the foot are the gills, arranged in longitudinal series, and usually about sixteen in number. The posterior opening of the food canal is at the extreme end of the body, as far as possible from the mouth.

FIG. 67.—*Chiton marginatus*, upper surface, showing the eight shells.

We cannot here go into the minute details of the structure of *Chiton*, but may briefly call attention to its more salient features. It is a true Mollusc; it has a *mantle* which secretes the dorsal shells, a ventral *foot*, it breathes by *gills*. It resembles the Gasteropods in the condition of the foot, and in possessing a radula or tooth-ribbon within the mouth. *But* it differs in many respects from the Gasteropods. Instead of having one shell it has eight; in place of the single gill of most Gasteropods it has eight pairs; instead of being unsymmetrical, with the organs apparently twisted to the right, it is perfectly symmetrical with mouth at one end and anus at the other, like worm or Arthropod. In brief, it is a simple and primitive form. It should be especially noticed that it resembles worms and Arthropods in showing traces of *segmentation*. We have already noticed that in both these groups the body is made up of a repetition of similar parts—is distinctly segmented. Now in the Mollusca such segmentation is typically absent, its absence being one great point of contrast with the Arthropods. The number of shells in *Chiton*, and their relation to the gills, point, however, to the existence of segmentation in this primitive form. This is a point of much interest to those who care about problems of origin.

The species of *Chiton* are chiefly distinguished by the minute characters of the shells. The commonest form is *Chiton marginatus*, and is very variable in colour and size, but is distinguished by the finely granular surface of the valves. Each valve has a slight central keel prolonged posteriorly into a small beak, and is divided into three areas by two diverging lines. All the areas are similarly marked with fine dots, sometimes partially rubbed off in old specimens. The colour is usually greenish, marked and dotted with pale colour, but bright red varieties also occur.

Another common and much prettier species is *C. fascicularis*, characterised by its comparatively small valves, and by groups of bristles placed on the margin of the mantle. There are eighteen of these groups, four being placed in front of the first valve and a pair in front of each succeeding valve. The individual valves should be examined with a good lens, when their brilliant colouring and beautiful markings are clearly seen. Each has a central ridge ornamented by coarse longitudinal lines and ending in a beak, and two lateral areas ornamented by curious "tear-shaped" granules, whose pointed ends are directed towards the beak. The sculpture as a whole is interesting and very characteristic.

Another species, *C. ruber*, easily recognised but not very common, is of a bright, shining red colour, marked and variegated with white. The surface of the valves is perfectly smooth and without trace of sculpture.

By far the commonest species is *C. marginatus*, which is abundant everywhere on shore rocks. It is almost confined to the littoral zone, and is very variable.

After the Chitons we come to the Gasteropods proper, in which the shell, when present, is always simple and often coiled. The classification is a matter of some difficulty, for those now in use depend upon anatomical details which are somewhat beyond our scope. We shall consider the true Gasteropods as divided into three orders: (1) the Zygobranchia, (2) the Azygobranchia, (3) the Opisthobranchia. The first order includes the limpets, of which there are many kinds. Sometimes two gills are present, sometimes only one, as in *Acmœa*, while in yet other cases, as in *Patella*, there is no gill at all. The name, which signifies "gills paired," is therefore a little deceptive. The shell is usually cap-shaped, and never more than very slightly coiled. In the general case there is little difficulty in recognising the common limpets.

The Azygobranchia ("gills unpaired") include the great majority of the snail-like Gasteropods of the shore. The shell is usually large and coiled, and there is a single gill. The third order, the Opisthobranchia ("gills posterior"), includes forms which are often not easy to recognise as Molluscs at all. The shell is often absent, and is never well developed. When a gill is present it is placed *behind* the heart, instead of in front of it as in other Gasteropods; but usually there is no true gill, its place being taken by outgrowths of the mantle. Often brilliant in colour and quaint or beautiful in form, there is at least no fear of confusing the Opisthobranchs with other Gasteropods. They are very abundant on the shore, especially at certain seasons of the year; the commoner forms are called sea-slugs or sea-lemons.

For clearness let us briefly summarise this classification of Gasteropods, or Molluscs in which the foot forms a ventral creeping sole.

GASTEROPODA.

1. Zygobranchia, limpet-like forms, generally with simple, more or less conical shell.
2. Azygobranchia, forms like whelk and periwinkle with coiled shells.
3. Opisthobranchia, forms in which the shell is often absent and never well developed.

The Chitonidæ with eight shells and eight pairs of gills are often separated from the true Gasteropods.

We shall take first the limpets as representatives of the Zygobranchia. On the East Coast, at least four of these are common between tide-marks. Commonest of all is *Patella vulgata*, *the* limpet of the fishermen, which is too familiar to need description. It is always abundant between tide-marks on rocky coasts, and is often found in little pits or depressions of the rock, into which the shell exactly fits. It has been shown by experiment with marked limpets that each limpet has its own particular habitation, to which it retreats as the water begins to ebb. When the rock on which the limpet has settled down is covered again with water, however, the limpet sets out in search of the Algæ which form its food. As it travels it forms a broad track, often very distinct where it has crossed sand or muddy rock. Experiments on the "homing instinct" of limpets are easily made, and can be carried out at neap tides on days when other shore work is largely stopped. The common limpet is in great demand for bait on most parts of the coast. It seems popular with most fishes, a somewhat curious fact since it is so purely littoral in habit. It is in many ways an interesting species, and the student should not fail to watch the way in which the peculiar tongue is used to mow down the small Algæ on which it feeds. As it glides over the rocks the long tentacles are moved about in all directions, and show clearly the small eyes at their bases. The position of the eyes should be contrasted with that seen in the garden snail (*Helix*), where the eyes are borne at the *end* of the long tentacles. Most common marine Gasteropods have eyes placed in the position seen in *Patella*.

The next limpet we shall consider is a much prettier form than *Patella*, and in its own area almost as common. To find it we must choose a spring tide, and tramp steadily outwards till we top the last reef, and come down to the sea-meadows where the giant *Laminariæ* flourish. Choose a spot where you can look down on the floating fronds, and you will see that they are spotted with tiny shells of the same tint as the weed, but barred with radiating lines of shimmering blue. The colour is of the kind known as optical, and as the long fronds sway gently in the water, its living jewels glow blue or green according as the light touches them at one angle or another. When first seen under favourable conditions this is one of the sights which stay in the memory, for there is something in the exact harmony of colour between weed and shell which seems to give the blue colour an added glow. Beautiful as the limpets are, however, they are not quite harmless companions for the oar-weed, for you will find that they eat very considerable holes in its fronds, in spite of their small size as compared with them. Pull up a plant of *Laminaria* by the roots, and embedded in these, in company often with many other strange creatures, you will find another variety of the limpet. While the first variety is a thin, delicate, transparent shell, brown in colour with blue rays, the second is much stouter, paler in colour, and usually without trace of the blue rays. The first is the typical *Helcion pellucidum*, the second *Helcion pellucidum* var. *lævis*. The first eats the fronds of the oar-weed, and so produces those torn and ragged fragments which are constantly thrown on the beach; the second, by burrowing in the roots must weaken these, and so assist the waves in tearing up the great plants which appear on the shore after every storm. They usually bring with them many curious and beautiful creatures, so the naturalist has some reason to be grateful to the tiny limpet.

The transparent limpet is closely related to *Patella*, and in the absence of a true gill differs from the next two limpets, *Acmæa testudinalis* and *Acmæa virginea*, which both possess a delicate white branchial plume. In habitat they offer the same contrast as *Patella* and *Helcion*, for while the tortoise-shell limpet is to be found not far below high-tide mark, *Acmœa virginea* is only to be found among the *Laminariæ*. We have, however, already (p. 24) seen that *Acmœa testudinalis* differs from the common limpet in being confined to the pools, and in never climbing high above the water level, as *Patella vulgata* does. It is a pretty little creature, easily recognised by the distinct pattern in brown on the shell, and the very dark brown "spatula" or mark in the inside of the shell. The mantle is bright green and the eggs bright red, so the animal does not lack bright pigments. The allied form, *A. virginea*, is of similar size and appearance, but has the shell ornamented with rays of pink instead of the brown network of the other species. The spatula is not brown, and the mantle has not the vivid green colour of the tortoise-shell limpet. It will be found attached to shells and stones in the Laminarian zone. On the South and West Coasts other limpets will be found in addition to these four.

FIG. 68.—Tortoise-shell limpet (*Acmœa testudinalis*).

After the limpets we come to the Azygobranchs—periwinkles, whelks, dog-whelks, and similar forms, with strong spiral shells and active habits. To make sure of them collect on the shore a handful of common forms, such as the large whelks, very common in some places under muddy stones, a few periwinkles, some living tops ("silver Tommies"), or any other spirally coiled shells which catch your eye, and drop them into a basin of clean water. Note the different shapes of the shells, largely dependent upon the number and shape of the coils, and also the fact that while some of the shells have smooth rounded mouths, others, such as the whelks, have the mouth prolonged into a canal. Note, too, the general characters of a coiled shell; all have a central pillar or columella, a large body-whorl, a spire made of other smaller whorls, a mouth with outer and inner lip, and so on. Another point will be very obvious, namely, that not only can the animal retreat into its shell in a way which is impossible for a limpet, but that when it does retreat it "shuts the door" behind it, by means of a firm plate, or operculum (*o* in Fig. 70), so placed as to block the mouth of the shell when once the animal has withdrawn into it. If the chief function of the shell be for protection, then the shell of the Azygobranchs is more efficient than the shell of the Zygobranchs.

While you have been making these observations, some of your specimens will have recovered from their alarm, and have begun to crawl about the basin. In such expanded specimens notice as before the creeping foot (*f* in Fig. 70), not unlike that of the snail, and also the relation of the operculum to it. A comparison of forms with notched and unnotched shell will show further that in the former a long tube or siphon (see Fig. 70, *s*) can be protruded along the canal or notch. This siphon is a specialised portion of the mantle, and conveys water to the mantle-chamber in which lies the gill. You will remember that in the tortoise-shell limpet the gill itself is protruded as the animal walks; but gills are delicate, easily injured structures, full of blood, and not to be exposed without some risk, therefore we find that with the specialisation which gives the Azygobranchs their more complex shells, there is usually more efficient protection for the gill, which is now usually hidden permanently within the mantle-chamber. Lest, however, in this position the gill should not be sufficiently exposed to the purifying action of the water, there is in many cases a long siphon which conveys a current of water to the mantle-chamber. We have already noticed a similar condition of affairs in the Crustacea, where in the higher forms the position of the gills in a gill-chamber necessitates very elaborate arrangements for renewing the water. Curiously enough it is found that almost all the siphonate Azygobranchs are carnivorous, while those without siphons are vegetarian. The former are more specialised than the latter.

Notice, also, that the Azygobranchs have a much better developed head region than the limpet. It is often prolonged into a proboscis, which may, as in the whelk, be capable of being protruded and retracted. The tentacles are often very long, and in some cases, as in the tops, there are numerous tactile processes in addition to the tentacles proper.

While the limpets lay their eggs singly in the water, the Azygobranchs lay them in clusters or capsules which are often curious and interesting in appearance, and in several cases are among the commonest of the objects found on the seashore.

Among the Azygobranchs we shall begin with the familiar "silver Tommies" of our youth, the "tops" of south-country children, and the *Trochi* of scientists. All children recognise at least two varieties, the common "silver Tommies," valuable only in very early youth, and the large pink ones, which, with the finer scallops, constitute the gems of all early collections. The common form is *Trochus cinerarius*, and can always be found in the living condition on the rocks; the large is *T. zizyphinus*, and is an inhabitant of deeper water, sometimes tossed on shore after storms. There are, however, especially in the South, very many other species, some of which live in deep water, and others on the tidal rocks. Choose the species which is most abundant in the locality at your disposal—it will probably be *Trochus cinerarius*—and study it in the living condition. Notice the small conical shell, with its rounded, un-notched aperture—the animal has no siphon, and is vegetarian. As it protrudes itself from the shell, notice the operculum borne on the foot, the foot itself, narrow in proportion to its length, the large head prolonged into a non-retractile snout, and bearing two long tentacles, and two eyes placed on short stalks, which spring from the base of the tentacles. Between the tentacles are two distinct "head-lobes," while to their outer sides lie two greatly developed "side-lobes," with long, delicate processes, or cirri (see Fig. 69). The cirri move about as the animal progresses, and add considerably to its appearance. The operculum is peculiar in being spirally coiled, as it is in all the *Trochi*.

FIG. 69.—*Trochus zizyphinus*, with head partially protruded. Note the tentacles and lateral cirri.

As to the special characters of the shells of the different species, in *T. cinerarius* the whorls are somewhat flat, and six in number, the base of the shell shows a narrow hole called the umbilicus, the shell is marked by coarse, spiral lines, and is of a dull ash colour, marked by oblique lines of darker tint, which run in the opposite direction to the lines of growth. Shells found on the beach often have the outer coat rubbed off, and are then "silvery," that is, they show the mother-of-pearl lining.

The large *Trochus zizyphinus* (see Fig. 69) is on the east an inhabitant of deep water; on the west it occurs between tide-marks, and the shell is common on most shores. The shell is conical in shape, and may reach a height of over an inch, the base is without a perforation, there are eight or ten whorls, and the shell is usually spotted with bright rose colour. In the general case the species is readily recognised.

There are very many other species of *Trochus* found in Britain, some in deep water, and some found in the tidal pools in the South and West.

The next set of forms we shall consider are the periwinkles, an interesting and puzzling group. As the name of the genus—*Littorina*—indicates, they are purely littoral forms, living almost exclusively between tide-marks, and showing much tolerance of fresh water and of dryness. On the one hand they are related to the genus *Lacuna*, whose members inhabit the Laminarian zone and deeper water, and on the other they are connected with *Paludina*, a genus of fresh-water forms, and they occupy every variety of habitat between those of these genera. High up on the cliffs, out of reach of all but the spray, on the stones of the streams which run down the beach, on the tidal rocks, on the broad blades of *Laminaria*, there are few localities on the shore in which the ubiquitous periwinkles do not occur. It is true that in most cases the different localities are characterised by one dominant form, but in not a few cases the species themselves have a wide range, and I have picked four so-called species off one stone. You probably do not need to be told that this is very exceptional, and for a very obvious reason. It is an axiom of the modern theory of evolution that those divergences of structure which ultimately result in the formation of new species have been produced by divergences in the environment. Take as an example the two species of porcelain-crab already considered (p. 179). The minute porcelain-crab is adapted to one environment, the hairy porcelain-crab to another, and their differences are directly associated with the differences in their surroundings. The latter, by virtue of its hairy coat, can live among mud, which the former cannot. It, on the other hand, from its superior agility, can probably escape enemies which the other could not, and is therefore enabled to live in more exposed places. If hybrids between the two were to occur they would probably be well adapted for the habitat of neither, and so would tend to be eliminated. In other words, marked and permanent differences of environment tend to produce marked and permanent differences in species.

If we return to the periwinkles we find that there is no such marked difference in the environment in this case. They are tolerably active animals, and therefore, though each species may theoretically have its own zone, its members seem to wander freely into the zones of other species. This must have two consequences. In the first place, divergence will be probably checked by constant interbreeding; secondly, if the adults wander freely, their adaptation to any particular locality cannot be very exact, and there is no reason to believe that hybrids will be more likely to be eliminated than pure forms. That is, the species should not be well defined. Now this is what actually occurs; there are a great number of periwinkles, and in many cases it is almost impossible to distinguish between species and varieties. There can, I think, be no doubt that this is due to the continuity of the environment. It naturally, however, makes the identification of species very difficult, and the distinction of species a fruitful source of controversy. A modern will no doubt say their distinction is a matter of no importance; but if the attempt makes clear the meaning of variation, it is not without its usefulness.

Let us first answer the question, What is a periwinkle? All the periwinkles have solid top-shaped shells, with a short spire and an entire mouth. The surface of the shell is sometimes smooth, sometimes spirally grooved. The mouth is nearly circular, and has a sharp-edged outer lip, while the other or columellar lip is expanded. The operculum is pear-shaped, horny, spirally coiled, with its centre, or *nucleus*, laterally placed. In the living animal the head is seen to bear two tentacles, which have two almost sessile eyes at their bases. There are no lobes nor cirri such as occur in *Trochus*. The foot is rounded at both ends, and has a very distinct central groove. Make out these points on a living common periwinkle, and then make a special journey to the rocks to collect the different forms in the living condition. Begin at high-tide mark and collect specimens down to low-tide mark. Then, either indoors or at the rocks, sort your specimens carefully. Pick out first the common periwinkle (*Littorina littorea*), which is known by sight to most people, and is almost always easy to recognise. The shell is usually black, sometimes brown or red; in the young the surface is ridged, but the adult shell is often nearly smooth. Having put aside all the specimens which are obviously the edible kind, take out from the remainder those with distinctly flattened spire, in which the coiled part of the shell seems to be sunk into the last whorl. This is *L. obtusata*. The shell has a peculiarly smooth surface, and is very variable in colour, being usually shades of yellow and brown. It lives chiefly among bladder wrack (*Fucus*). Among the remaining specimens you will find a number of yellowish colour, often banded, which, except for their colour, present much general resemblance to the common periwinkle. From it they differ especially in the greater roundness of the whorls, and in the breadth of the outer lip of the mouth, at the point where it joins the columella, or pillar, which forms the central axis of the shell. The result of this broadening of the outer lip is to give the aperture the appearance of being partially filled up. This form is *L. rudis*, a species which lives near high-tide mark, and is very variable, giving rise to several more or less distinct varieties. The most distinct of these is the form called *L. patula*, which has an ear-shaped shell with a somewhat oblique spire. There are other species or varieties, such as *L. neritoides*, a small form living above high-water mark; but if those mentioned above are distinguished the observer will do well.

The special characters of the forms named may be briefly described. The common periwinkle, *Littorina littorea*, is defined by the combination of the following special characters: the surface of the shell, especially in the young stage, is marked by striæ, the whorls are more or less flattened, the outer lip of the aperture joins the last whorl at an acute angle, and is more arched below than above. On the last point special stress should be laid, as it is very characteristic. The colour of the shell has been already described; as to the colour of the living creature, the fact that the horns and tentacles are spotted and ringed with black is especially noteworthy.

It is much easier to distinguish between actual specimens of *L. littorea* and the next species, *L. rudis*, than it is to say wherein the difference actually consists. In the latter the whorls are distinctly rounded, the outer lip joins the last whorl at a right angle, and is more arched above than below. This, which is an important difference from the common periwinkle, may seem a very trivial matter, but it has, in reality, considerable bearing on the life-history. The common or edible periwinkle lays eggs on *Fucus* in little jelly-like patches, a habit which is no doubt the primitive one for the species. But such a habit is obviously impossible for forms like *L. rudis* and its varieties, for they inhabit localities often not covered by every tide, and unsuited to the growth of the tangles. It therefore retains its eggs within the body until the young develop, and they are subsequently born already furnished with shells. There can be little doubt, I think, that the shape of the shell-mouth bears a direct relation to this viviparous habit—it allows room for the young to develop, and makes birth easy. Practically, the viviparous habit is of some importance, because it renders this species unfit for food, owing to the grittiness imparted by the presence of the young during several months of the year. The species never reaches the size of the preceding.

The form called *L. patula* is merely a variety of *L. rudis*, but lives even further up on the shore. It is usually smaller, has a thinner shell and a more stunted appearance, the whorls, especially the last, are more expanded, and the aperture of the shell is wide. As in *L. rudis*, the tentacles of the living animal are usually marked with longitudinal stripes, not with rings or spots, as in *L. littorea*.

Typical examples of *L. obtusata* are so easy to recognise that it seems unnecessary to describe their characters further than to re-emphasise the peculiar flatness of the spire.

The four types given here have been chosen because I have found them to be the most abundant on the shores of the Firth of Forth, but the periwinkles of any area form a most interesting study.

Related to the periwinkles are two genera of minute shells, which we can only mention without description. The first of these is the genus *Rissoa*, which includes a great number of British species, inhabiting very various depths of water. To obtain examples pluck a good handful of any of the finer seaweeds, and drop into a dish of sea-water. Presently there will crowd to the surface numerous minute forms with spirally coiled shells often beautifully sculptured. They are active little creatures, crawling over the seaweed, or taking advantage of surface tension to creep along the surface of the water, shell downwards. The other genus is *Skenea*, including especially *Skenea planorbis*, a common shore form with a circular depressed shell. It is very minute, being just visible to the naked eye.

On many parts of the coast "tower-shells" (*Turritella*) are found very commonly thrown on the beach. There is only one British species (*T. communis*), and it is an inhabitant of deep water, so that the living animal is not likely to be found. The shell is elongated and tapering, it has sometimes as many as nineteen whorls, of which the first ten bear three distinct ridges. The aperture is entire and rounded. The shell is usually of a brownish colour, and may be over two inches in length.

Though Molluscs which only occur in the dead state are, strictly speaking, somewhat outside our scope, we must mention the curious "pelican's foot," *Aporrhais pes-pelecani*, which is not infrequent on the shore. The shell is turreted, very strong, with numerous ornamented and ribbed whorls. The mouth of the shell is furnished with a short canal, and in the adult its outer edge is expanded into a large lobed plate. The shell is interesting on several accounts, especially because it is in some respects transitional between the Azygobranchs, with round entire aperture like *Trochus*, and those with canaliculate, or notched aperture like *Buccinum*. The living animal is beautifully flecked with scarlet, and may occasionally be found flung ashore after storms.

Before passing to the siphonate Azygobranchs, we must mention one other form not uncommon in some places between tide-marks which is very different in appearance from its allies. This is *Lamellaria perspicua*, especially interesting because the shell is very thin, and is completely covered by the mantle. This reduction of the shell occurs in many different sets of Gasteropods, but is rare in the littoral Azygobranchs. In *Lamellaria* the body is very convex, without external trace of shell, is usually yellowish, but may be white or purplish. The head bears two tentacles, with small eyes at their bases. The animal is very active, and may reach a length of two inches, but between tide-marks specimens are usually of very much smaller size. It is possible, by very slight dissection, to find the concealed shell which lies in the middle of the back, and is of a delicate white colour, with a mere trace of a spire. The living animal is apt to puzzle the beginner very much, for it has few characters which can be very definitely laid hold of, and specimens between tide-marks are not infrequently of very small size. On the dorsal surface notice the rounded mantle, often highly spotted and marked, and with a very characteristic notch anteriorly over the head, which serves as a kind of siphon to admit water to the small chamber in which the gill lies. When the animal crawls it trails a translucent foot behind it, while the long, slender tentacles project in front. If it be turned over, the broad, creeping surface of the foot will become very obvious, and also the large, black eyes at the base of the tentacles. The animals are to be found under stones between tide-marks, and on account of the activity of their movements are very charming occupants of an aquarium.

Of the carnivorous siphonate Azygobranchs, the common *Purpura lapillus* is perhaps the most abundant on the shore. Like many of its allies it yields a purple dye similar to that which furnished the ancients with their famous Tyrian purple. In some places it is called the dog-periwinkle, and is one of the most variable of shore animals, and one of the most abundant. It is purely an inhabitant of the littoral zone, and lives upon other Molluscs, chiefly Bivalves, which it attacks by first drilling a round hole in the shell, and then sucking up the soft contents by means of its protrusible proboscis. At low tide the dog-periwinkles remain motionless attached to the dry rocks, but they have a curious habit of suddenly relaxing their hold and dropping into the pools beneath. Beneath overhanging rocks their egg capsules may be found at all seasons, sometimes empty and sometimes full, and not infrequently stained with the creature's purple dye.

The shell is very strong, usually white or pale yellow, with a very large body-whorl and a distinct but short canal, and in the adult reaches a length of over an inch. The surface is usually nearly smooth, but in one variety the lines of increase rise up to form "fringe-like imbricating lamellæ," and there are in addition spiral ridges placed very close together. The colour is very variable, the shell being sometimes banded with dark brown and sometimes entirely dark brown; the shape is also variable.

The living animal is pale in colour, usually white. Behind the head lies the gland which secretes the colourless fluid from which the purple dye is obtained by exposure to the air. The egg capsules are little oblong, shortly-stalked cups, and are placed in clusters on stones and shells.

The next two species belong to the genus *Nassa*, and are usually more abundant as shells on the shore than in the living condition. The shells are prettily marked, and in the young state are often collected by children in quantities to make necklaces or ornaments. Both species are sometimes found living near low-tide mark.

The larger species, *Nassa reticulata*, has a thick shell of pale brown colour, which may reach a length of one and a half inches. It is covered by numerous convex ribs, which are crossed by spiral grooves, producing a netted appearance. The aperture is prolonged into a short and broad canal. The animal is yellow, speckled with black, and has the foot prolonged into two filaments, usually carried upright when the creature walks.

The other species, *N. incrassata*, is much smaller, has the whorls of the shell rounded, and a dark spot placed at the origin of the canal. The aperture is largely filled up by a projection, or varix.

The next form is a very interesting one—it is the common whelk, or "buckie" of Scotch children. Between tide-marks it is usually small, but in deeper water grows to a length of six inches, and in many places is much valued both as food and bait. It is very widely distributed and common, and, like so many other common shore Gasteropods, is very variable, tending especially to run into local varieties. It is extraordinarily abundant between tide-marks in the Firth of Forth, where it lives chiefly in mud and sand, and is often beautifully coloured. The egg capsules are very common objects in autumn and spring, both on the shore rocks and cast up among the refuse on the sand. They are interesting objects and well worth study. Each capsule has a tough wrinkled coat and is of irregular shape, and the capsules are aggregated together in masses varying in size from a small cluster like half a lemon to a mass as large as a child's head. The spawning season is in autumn, though, as in many Molluscs, it seems to be of long duration. Each *capsule* when laid contains 500–600 eggs inclosed within a space of a quarter of an inch to half an inch in diameter, so that some estimate may be formed of the enormous number of eggs produced by the parent. Relatively very few of these eggs, however, develop. For some reason not yet adequately explained, some five or six in each capsule get the start, and begin to develop rapidly. As they do so they devour their less successful brethren, and on opening the capsules one finds the infant monsters with their transparent bodies distended by some seventy to eighty undeveloped eggs. By the help of this food they are enabled to remain within the egg-case until the shell is fully formed, when, in spring, they finally leave it, and begin life on their own account. This sacrifice of many eggs to the few which develop is common among shore Gasteropods, but it can be observed perhaps most readily in the common whelk.

Whelks are probably more or less familiar to most people, so it is not necessary to describe them in very great detail (see Fig. 70). The living animal is both interesting and beautiful, and an attempt should be made to keep a few specimens in confinement. To do this with success it is necessary that they should be supplied with a considerable bulk of water. In such living specimens notice the strong operculum (*o*) with which the shell can be entirely closed, the large creeping foot (*f*) beautifully mottled and speckled with black, the long siphon (*s*) which is protruded along the canal of the shell and waves freely in the air as the animal walks, the broad head (*h*) with the pointed flattened tentacles bearing the distinct eyes, and the long proboscis which can be protruded from the mouth. The shell varies considerably in colour, but is usually more or less brownish; it is spirally grooved and striated, and usually marked with oblique transverse undulations which do not traverse the whole of the body-whorl. It is very thick and strong, especially in forms from deep water. It is not usual to find the whelk abundant between tide-marks except in the North, but, as already noticed, it is very common on the coasts of the Forth.

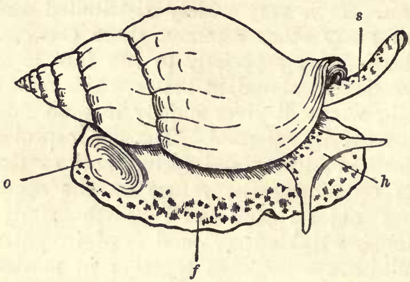

FIG. 70.—Common whelk (*Buccinum undatum*), showing the animal as it appears when crawling. For explanation of letters see text.

Allied to *Buccinum* is the genus *Fusus*, whose members are called spindle-shells, or red whelks, or buckies. The two commonest species in the North are *F. antiquus* and *F. islandicus*. Both are inhabitants of deep water, but are sometimes thrown up in the living state by storms. The shells are common on the shore at all seasons, and are not infrequently found in rock pools occupied by hermit-crabs. A full-grown hermit requires for his accommodation an adult shell of *Buccinum* or *Fusus antiquus*, and when the latter is chosen the result is singularly beautiful. The shell is usually pure white, the colour deepening into yellow within the large aperture. It may reach a length of over six inches and is always peculiarly graceful in shape. The shell of *Buccinum*, on the other hand, is only beautiful when small, the large specimens tending to become thick and clumsy. The other species of *Fusus*, *F. islandicus*, is much smaller and more distinctly spindle-shaped; the two species may be recognised and distinguished by the following characters. In the larger species the surface of the shell is covered by numerous strong striæ placed very close together. The mouth is very large, being longer than the spire, and about twice as long as it is broad. The result is to produce a shell which is very wide at its lower part and only tapers very gradually above. In *Fusus islandicus* the surface is covered by relatively few striæ, separated from each other by an interval broader than they are themselves. The mouth is not so long as the spire, and the breadth is only about a third of the length. In consequence the body-whorl is narrow, and tapers suddenly to a somewhat sharp point.

The only other of these Gasteropods we shall mention is that curious little one known as the "blackamoor's tooth," or cowry, which is so common on the beach, and is so often collected in hundreds by enthusiasts who spend the greater part of their summer holiday poring over the beds of gravel in which the little shells are found. I have often wondered whether the results in the shape of long necklaces of perforated shells are worth the labour and the backaches of the gathering. The living animals, however, are exceedingly interesting, and may sometimes be found on the rocks near low-tide mark. When fully expanded two bright orange folds envelop the shell so as to almost conceal it. The tentacles are very long, and, like the rest of the head, the foot and the siphon, are of a pale yellow colour. When very young the shell is coiled as in most Azygobranchs, but as it grows the spire is concealed by the growth of the body-whorl, and the inflection of the lip produces the long narrow aperture so characteristic of the cowries, to which family the present form—the *Cyprea europæa* of systematists —belongs. The living animal is a most gorgeous little creature, the prevalent orange tint being often set off by bands and markings of other colours, or replaced by a pinkish colour. The shell is quite white, as is often the case with concealed shells.

KEY FOR IDENTIFICATION OF MOLLUSCA DESCRIBED IN THIS CHAPTER.

CHITONIDÆ, one genus, *Chiton* . .	8 shells, 8 pairs of gills.
Surface of shells finely granular .	*C. marginatus.*
Surface quite smooth. Colour red .	*C. ruber.*
Mantle with tufts of bristles . .	*C. fascicularis.*

(1) GASTEROPODA ZYGOBRANCHIA (shells cap-shaped).

Gill absent, replaced by folds of mantle .	Shell with strong ridges . . .	*Patella vulgata.*
	Shell quite smooth and delicate . .	*Helcion pellucidum.*
One gill present .	Shell with tortoise-shell pattern in brown . . .	*Acmæa testudinalis.*
	Shell marked with radiating pink lines	*Acmæa virginea.*

(2) GASTEROPODA AZYGOBRANCHIA (shells spirally coiled).

(*a*) Forms without a siphon.

Shells more or less top-shaped	Base flat, shell pearly inside, whorls numerous. Animal with cirri.	*Trochus* . .	*T. cinerarius*, shell with hole at base, six whorls. *T. zizyphinus*, no hole, eight to ten whorls.
	Shell thick, not pearly, whorls few. No cirri.	*Littorina* .	*L. littorea*, shell red or black, surface ridged. *L. obtusata*, surface smooth, spire flattened. *L. rudis*, whorls round, lip thickened.
Shells very long, with many whorls . .	Whorls spirally striated	*Turritella communis.*	
	Whorls with tubercles, outer lip expanded into plate . .	*Aporrhais pes-pelecani.*	
Shell very thin, concealed, mantle with anterior notch	. . .	*Lamellaria perspicua.*	

(*b*) Siphonate forms.

Shell oval, spirally sculptured, canal short . .	Spire sharp-pointed, canal narrow . .	*Purpura lapillus*, shell white or banded.	
	Spire short, canal short and recurved, columella with fold at base . .	*Nassa* . .	*N. reticulata*, shell large. *N. incrassata*, shell small, aperture much narrowed.
	Spire blunt, canal open and deep .	*Buccinum undatum* shell undulated.	
Shell spindle-shaped, with long straight canal . .	*Fusus* . .	*F. antiquus*, striæ numerous, body-whorl wide. *F. islandicus*, striæ few, body-whorl narrow.	
Shell with concealed spire, aperture very narrow .	*Cyprea europœa.*		

For (3) Gasteropoda opisthobranchia, see next chapter.

NOTE ON DISTRIBUTION.

From the great multitude of shell-bearing Gasteropods we have been able to pick out relatively so few that not much can be profitably said as regards the distribution generally. Most of the forms mentioned occur all round the coast. The whelks *Fusus islandicus* and *Buccinum undatum* may be mentioned as forms commoner in the North than in the South, while the cowry (*Cyprea*) is an example of one commoner on the South and West, at least between tide-marks, than on the East Coast. We have already indicated that although the pretty tortoise-shell limpet is absent from the South and West, its absence is atoned for by many other curious and interesting forms. A similar replacement of species occurs among other genera. Thus at Lynmouth, on the north coast of Devon, the common grey top (*T. cinerarius*) appeared to be absent, but the pools were filled with two other species—a small one prettily marked with brown (*T. umbilicatus*), and a larger dark-coloured one (*T. lineatus*). But, allowing for such cases, it may be said generally that the Gasteropods which are hardy enough to live between tide-marks are also hardy enough to live all around our coasts.

CHAPTER XIII.

THE SEA-SLUGS.

General characters of Opisthobranchs—The sea-hare—The sea-lemons, or Dorids—Five common species—The spawn and breeding habits —Development—Goniodoris, its structure and habits—Some other sea-slugs—General characters of the colouring—Their inedibility and its causes—The Eolids—Three common species—General notes on sea-slugs.

WE now come to a singularly interesting and beautiful group of Gasteropods, mostly without shells, and often of very singular shape. They constitute the group of the Opisthobranchs, and, as already seen, are characterised by the fact that the heart is in front of the gill when this is present, instead of being behind it, as in the Gasteropods just considered. The greater number of these shell-less Gasteropods are often called sea-slugs, or Nudibranchs ("gills exposed"), and certain sea-slugs are abundant on every shore. Most of them, especially the smaller kinds, live well in confinement, and should be studied in the living condition. They do not preserve well, both colour and shape being usually lost even under favourable conditions, and they are rarely to be found in museums; so that unless you draw and describe your specimens as you find them, there is little chance that you will be able to name them afterwards. Again, many of them seem to be more or less migratory in their habits, and are not found between tide-marks except at the breeding season. As this usually falls in the colder months, you can hardly hope to find such species if your visits to the shore are confined to the summer. In March, for example, I have seen the shore rocks whitened by the spawn of forms which in summer are rare, but at this time occurred in clusters of five or six at every patch of spawn. One other point,—the rocks at your disposal may abound with some of the smaller and more delicate forms, and yet you may be unable to find a single specimen. It must be remembered that out of water many of the sea-slugs collapse into a shapeless mass, while in the water they may so closely resemble the corallines or zoophytes among which they live as only to be distinguished with great difficulty. I do not know any more laborious task in shore hunting than crouching beside densely fringed pools and searching every weed for the tiny sea-slugs. I do not deny that the result is worth the trouble when some delicately tinted beauty rewards the search, but the trouble is not slight. However, storms are often kind to the ardent collector, and will toss up fragments of weed covered with zoophytes, among which many a prize may be found. Such fragments are always worth careful study, if found in the fresh condition.

The first Opisthobranch we shall mention is the sea-hare (*Aplysia hybrida*, see Fig. 71), an animal unfortunately rare on the North-east Coast. I have found it between tide-marks, but its habitat is among beds of weed in the Laminarian zone, and especially among the blades of *Zostera*—that strange marine flowering plant which grows at many parts of the coast, and is the favourite refuge of many curious animals. The sea-hare is an animal of singularly curious shape, with a characteristic smell, and a habit of pouring out a purple dye when alarmed. Round the animal and the dye many curious superstitions have clustered, especially in the Mediterranean, where the sea-hares grow to a large size, and have been known from ancient times. Those who are accustomed to argue that the wide distribution of a belief is a proof of its validity, will find some difficulty in fitting the sea-hare into their philosophy. The belief in its poisonous qualities is wide-spread, both among the ancients and among modern fishermen. Just as the gathering of poppies, or "thunder-cups," is likely to be followed by an avenging thunderstorm, so the foolish naturalist who wantonly handles the sea-hare will be smitten by fell disease. As far as my own experience goes, I may say that I think the one consequence is as likely to follow as the other, for the sea-hare is a perfectly harmless little creature, chiefly remarkable for its strange contortions and quaint shape.

So variable is the shape that the animal is not easy to describe. There is also considerable variation in colour; when young the whole animal is violet or purplish, while in the adult state it is greenish grey, speckled and mottled with brown and white. The shell is not visible externally, and the body is dome-shaped, the slender head projecting markedly in front. There are two pairs of tentacles, of which the upper (*t*) are shaped like hares' ears, and bear the small eyes at their bases. At the sides of the body two large flaps, or epipodia (*ep* in Fig. 71), rise straight up, and almost meet in the middle line of the back. If you fold back the epipodium of the right side you will see behind it the single gill, and the curious grape-shaped gland which secretes the purple fluid. Between the epipodia in the mid-dorsal line lies the thin, papery shell, almost entirely covered by the mantle. The foot, as usual, forms a creeping surface, but both it and the epipodia are very contractile, and in life are constantly changing shape. When the animal is actively crawling, the foot projects considerably behind the body. Such an expanded specimen may measure from two to four inches from tip to tip. Between the epipodia on the dorsal surface there projects a siphon-like process of the mantle, which leads from the anus to the exterior. On dissection it is easy to find the heart lying in front of the gill, the curious horny jaws in the mouth, and the gizzard armed with horny plates.

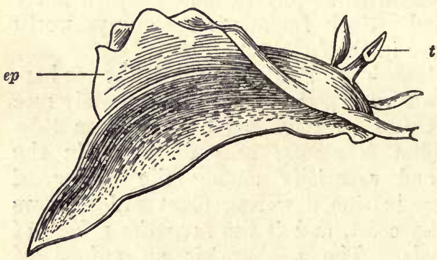

FIG. 71.—Sea-hare (*Aplysia hybrida*). After Gosse.

The next genus we shall consider is the very large one of *Doris*, including the true sea-slugs, or sea-lemons. By recent authors this genus has been broken up into a large number of small genera, but as we shall only consider some half-dozen species, it is not necessary for us to name these new genera.

The first species is very large, and is common in most places far out on the rocks. If at a low spring tide you go far out on the rocks and look carefully down the narrow clefts, you will probably see large weird creatures, yellowish in colour, soft to the touch, and shapeless in appearance. They often reach a length of over three inches, and are broad and massive. If you can successfully extricate them from the rock crevices, place your specimens in water and watch them unfold. There is no trace of shell, external or internal, and the branchial plume of *Aplysia* has also disappeared. The body is elliptical and depressed, and the head is not separated from it; the mantle-fold of the Azygobranchs is also absent. The dorsal surface is covered by what systematists call the cloak, or mantle, which is really equivalent to the epipodia of *Aplysia.* It is closely covered with round tubercles, and is strengthened by spicules. Through two little holes in it the short conical tentacles are protruded anteriorly. At the other end, also on the dorsal surface, is the median anus, which is surrounded by a circle of feathery "gills," not homologous with the gill of *Aplysia.* They are nine in number, are large and tripinnately cut, or fern-like, and can be completely withdrawn into the body. The foot forms a bright yellow creeping surface, and is as broad as the body. The upper surface in life is often bright in colour, with patches of blue-green on a yellowish ground. This is *Doris tuberculata,* the largest of our British Dorids. Like other species it lays white ribbons of spawn on the rocks, but the process is more easily observed in some of the more abundant species. I have not found it easy to keep in confinement, but there is usually no difficulty in obtaining specimens for examination, especially in the earlier part of the year.

The next species, *Doris johnstoni* (see Fig. 72), is rarer, but occurs occasionally between tide-marks. It is not very much smaller, for it may reach a length of two inches, but is readily distinguished by the different shape and the more numerous gills. The body is convex in the centre and markedly depressed at the sides; the dorsal surface is covered with very minute tubercles, and is blotched with brown on a ground colour of yellow or white. The dorsal tentacles are short and broad, and there are also a pair of slender oral tentacles at the sides of the mouth. There are fifteen tripinnate gills.

The next species is much more beautiful and much smaller. It is called *Doris repanda*, is usually about an inch long, and is of a dead-white colour, with a row of yellowish white spots down each side. The back is covered with indistinct rounded tubercles, and there are only five small gills. The oral tentacles are broad and flat and the dorsal ones long. Like most of the smaller species, this one can take advantage of the surface tension to creep along the surface of the water back downwards, and is then a

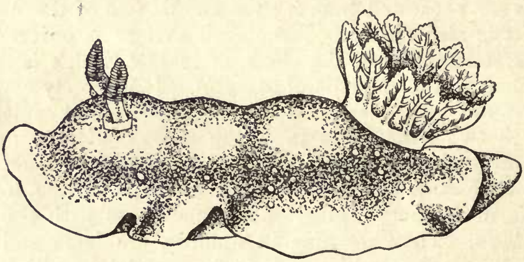

FIG. 72.—*Doris johnstoni.* Note the gill-plumes and the dorsal tentacles. After Alder and Hancock.

beautiful little object. The actively moving tentacles, the delicate branched gills, and the translucent whiteness of the tissues, make it a delightful occupant of an aquarium, but, like most of the Dorids, it requires some care in confinement, being apparently very sensitive to impurities in the water. It is not uncommon under stones on the shore.

Another species is *Doris bilamellata*, which occurs in the Firth of Forth in February and March in countless numbers. It is no exaggeration to say that in these months the rocks are simply whitened by these little creatures and their spawn. They are not particularly pretty, and show no brightness of tint as so many inedible or noxious insects do, but seem to enjoy immunity from persecution to a very marked extent. I have not found any shore animal which will eat them, and even the sea-gulls seem to leave them alone. Possibly the slime with which they are covered has something to do with their immunity. They have a curious habit of congregating, not in pairs, but in clusters of three to seven or so, and laying their eggs in continuous masses. The eggs are embedded in a tenacious jelly analogous to that which surrounds the eggs of frogs. By means of this jelly not only are the eggs attached together to form a ribbon about half an inch broad, but also one side of the ribbon is sufficiently sticky to adhere to the rock surface, and as the ribbons are laid in spirals, they stand up from the rocks like ladies' frills. Such ribbons are found on the rocks during almost all the colder months of the year, but are most abundant in February and March.

You should not fail to obtain a small stone bearing spawn, and carry it home with you to place in an aquarium. By means of a lens you can make an attempt to estimate the number of eggs in an inch of the ribbon, and so get an idea of the countless numbers of eggs laid by each individual. A few pages back we discussed the egg-laying habits of the whelk, and noticed the wholesale sacrifice of eggs which takes place within the egg-capsule. Nothing of the kind occurs here. If you are successful with your spawn you will find that from each egg a tiny colourless larva hatches out, so that the water of your aquarium becomes cloudy with the myriads of swimming specks. These larvæ are very different from the adults, and for a time are furnished with the shell which the adult has lost, and with a power of swimming of which the adult shows no trace. Stir the water in your aquarium gently, and notice how at every movement hundreds of larvæ are thrown up on the sides of the glass, there to speedily perish. Think of the wash of the sea over the shore rocks, of the dangers from enemies, and you will realise that, ruthless as the methods of the young whelks seem, they are probably justified in their results. It is probably better that many of the eggs should be sacrificed to feed the few, if these few are thereby enabled to remain within the egg-case until the early stages of their development have been passed through, rather than that all the eggs should be hatched in a condition when their power of resistance to unfavourable conditions is very slight. On the other hand, it should be noticed that the existence of a free-swimming stage in *Doris* must facilitate distribution. It is possible that the young may travel distances impossible to the sluggish adults.

To return to the special characters of *Doris bilamellata*. The body is about an inch in length and is greyish speckled with brown; the back is covered with numerous large unequal tubercles, and there are numerous simply pinnate gills.

A prettier species is *D. pilosa*, which is also very common in the Firth of Forth, and is about the same size as the preceding species. It is easily distinguished by its markedly convex shape, and the dense covering of slender soft papillæ on the back, which give it a "pilose" appearance. The colour is usually white, but is occasionally brown or even black. There are from seven to nine large gills which are not retractile, and the oral tentacles are broad and flat.

All these species are more or less common on the East Coast, and I have named them all because they are readily distinguished, and are worth careful study. There are a great number of other species, mostly rare or absent on the East, but in the Firth of Forth all those mentioned can be found without difficulty. They all occur also around the coast generally.

While hunting for species of *Doris*, you are almost certain to find an animal very like a *Doris* in appearance, but of somewhat different shape, and of delicate pinkish colour. The body is smooth, oblong, and elongated, the foot projecting markedly behind the cloak when the animal creeps. The cloak is almost a quadrilateral, and has a distinct keel down the centre. Its margin is reflected and indented posteriorly. There are thirteen simply pinnate gills which are not retractile. This is *Goniodoris nodosa* (see Fig. 73), a most graceful little creature, usually pink, speckled with white, but sometimes white or yellow. It reaches a length of about an inch, and is abundant everywhere under stones. The breeding season is in March (in the Firth of Forth), when the animals congregate in large numbers, and lay ropes of spawn, very different in shape from the frilled ribbons of *Doris*. This species lives fairly well in confinement, and is a great addition to an aquarium, where its more active habits and graceful shape make it preferable to most of the species of *Doris*.

The remaining Nudibranchs are nearly all beautiful, both in form and colour, but are so numerous that we can select only those which are fairly common between tide-marks. Unfortunately, none of them have common English names.

The first genus, *Triopa*, generally resembles *Doris*, but differs from it in the reduction of the gills, now only three in number, and the presence of slender outgrowths or processes at the sides of the back. In *Triopa claviger*, our only British species, the body is less than an inch long, and is white, variegated with bright yellow, a combination of colours which is very common among littoral Nudibranchs. It is an inhabitant of deep water, and is only rarely found between tide-marks.

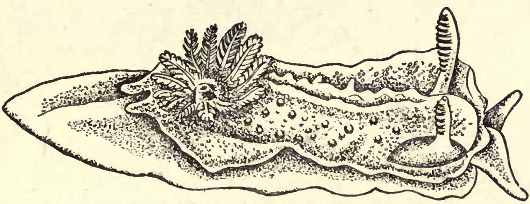

FIG. 73.—*Goniodoris nodosa*. After Alder and Hancock.

Another form, *Polycera quadrilineata*, is not uncommon near low-tide mark, and is singularly beautiful in appearance. It is pure translucent white, beautifully marked and spotted with bright yellow and black, the yellow spots being arranged in four lines running down the sides of the body. The tentacles are non-retractile, and the head bears, in addition to them, four to six processes, white tipped with yellow in colour. There are seven to nine simply pinnate gills, and close to the gills at either side a single golden-tipped process. It is to these processes with their beautiful colouring that the animal owes half its beauty. I have found it not infrequently among zoophytes and corallines at low spring tides. It grows to a length of about an inch.

A very similar but much smaller form is *Ancula cristata* (see Fig. 74), which is common between tide-marks in the

Firth of Forth, especially in spring. Its colouring is similar to that of *Polycera quadrilineata*, but there is only one yellow line placed in the middle of the back. The yellow tips to the processes are also often much less bright, the animal at times being wholly white. It is easily distinguished from the preceding form by the arrangement of the processes. These are absent on the head itself, but the stalks of the dorsal tentacles each bear two. There are three large bipinnate gills, and these are surrounded by a circle of yellow-tipped processes, instead of the two of *Polycera quadrilineata*. All these points are well shown in the figure. The animals live well in confinement, where they spend much of their time floating at the surface, back downwards.

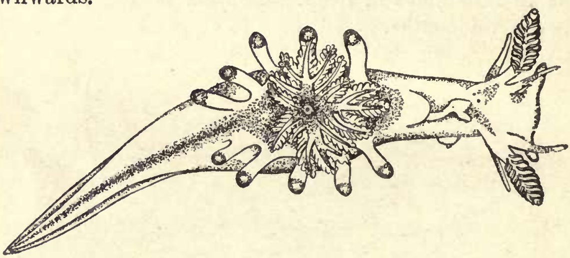

FIG. 74.—*Ancula cristata*. After Alder and Hancock.

The next form, *Dendronotus arborescens*, is regarded by many naturalists as the most beautiful of our sea-slugs. Its name and its beauty are both due to the fact that the back is furnished with numerous branched and brightly coloured processes, which make the creature look more like a dainty piece of seaweed than a living animal. Bright as the colours are, they harmonise wonderfully with the reds and browns of the corallines among which the animal lives, so that it is by no means conspicuous in natural conditions. Like most sea-slugs it is rarely if ever eaten by shore animals, so that the colouring, although it resembles the surroundings, can hardly be described as "protective," and it is certainly remarkable that colouring of this kind should be common among animals apparently rarely attacked by others.

Although *Dendronotus* can hardly be described as common between tide-marks, I have not infrequently found specimens there. They are, however, usually of small size, while specimens from deep water reach a length of two inches. As is the case with most of the shore invertebrates, the animals breed long before they attain the maximum size of the species, so that I have had specimens of under an inch in length which laid numbers of eggs in confinement. Facts of this kind are very apt to puzzle novices accustomed to land animals, whose life is more or less sharply divided into two parts—an early period of growth, and an adult period of reproduction. It should be clearly understood that such a condition of affairs is rare among marine invertebrates, which have usually no definite limit of growth, and which begin to reproduce very early. The result of this is that statements as to size are often very deceptive, for the limit given is usually that observed by some authority on the particular group, and the animals of the area at your disposal may show great variation as compared with this standard. Thus in the Firth of Forth the common starfish grows to a size much larger than the limit usually given, especially when it occurs in the vicinity of extensive mussel beds. On the other hand, in many cases the sea-slugs which congregate for breeding purposes are all distinctly below the standard of size as determined for other areas. It is not perfectly clear why marine invertebrates should differ so markedly in this respect from terrestrial forms, but there is no doubt that on the whole the conditions of life are easier on sea than on land. The high specific gravity of sea-water renders the support of the body an easy matter, while in a terrestrial animal, such as an insect, living in a rare medium, any additional weight would probably be a matter of great importance, and the limit of advantageous size is fixed more or less precisely for each species.

As to the special characters of *Dendronotus*, it has no gills of any kind, and the body is elongated, narrow, and prismatic in shape. The dorsal tentacles are placed in trumpet-shaped sheaths, which are prolonged into branched processes. Similar processes fringe the front of the head, and are arranged in tufts down the back. The body is some shade of red-brown, beautifully streaked and marbled with white; the processes are also red or crimson, the colour fading towards their tips as it does in most seaweeds. The animals are very active, continually creeping and twisting about. The eggs are yellowish in colour, and are laid in a close spiral with very narrow coils. I kept a pair in confinement for a long time, but rashly introduced a sea-anemone (*Actinoloba dianthus*) into their aquarium. In the course of their travels the sea-slugs crawled over part of the anemone, and it forthwith discharged its stinging-threads and killed the sea-slugs. They were not eaten, being, indeed, almost as large as the anemone, but simply killed, much to my sorrow, for they were beautiful pets.

It has been supposed that it is an important part of the function of the branched papillæ that they render *Dendronotus* and its allies inedible; but I can hardly believe that this is the whole explanation, for forms like *Ancula cristata*, which have relatively few papillæ and no brilliancy of colour, are also severely let alone by most animals. The aquarium in which the *Dendronotus* lived afforded some interesting results as to relative immunity to attack. Its chief occupant was a young Norway lobster of beautiful tint and large appetite, not very easy to satisfy. It was fondest of shrimps, prawns, and young crabs of various kinds, but had a way of eating these rather trying to the feelings of the onlooker, so I liberally supplied it with various sea-slugs, of which at the time I had a large stock. Colourless specimens of *Ancula cristata*, small Dorids, *Dendronotus*, and others, which seemed less alive than crabs and quite suited to the lobster's taste, were placed in his dish. But though the coat of a young spider-crab was no protection against the voracity of the *Nephrops*, the delicate sea-slugs crawled untouched over his body, while he seemed only anxious to get out of their way. When the anemone came on the scene, however, the conditions were largely reversed. The crabs seemed able to resist its deadly power to a much greater extent than the defenceless sea-slugs, who fell victims at once; but in natural conditions the sea-slugs rarely live in those dark and dank localities which suit this particular anemone. The experiment showed in an interesting way that the value of a protective device depends upon the environment of the protected animal, and must have a direct relation to this environment. It seems probable that the sliminess of many sea-slugs, like that of some worms, may render them unpalatable to many foes.

Much smaller than *Dendronotus*, but in its way quite as beautiful, is *Doto coronata*, a little animal occasionally found among corallines at the margin of the rocks. (The animal is shown in Fig. 4, p. 13, and the spawn in Fig. 75.) If you can pick it out from a dense cluster of the weed, you may flatter yourself that your eye has been tolerably well trained. One specimen may be found by chance, but if you are desirous of obtaining several for examination, you will find the need of patience exceeding that of Job. Place your specimens on green weed or in a light dish, and you may wonder at their conspicuousness, put them back among the corallines and zoophytes and they seem to disappear from sight. Not only is there no definiteness of form, no difference of colour to catch the eye, but the colours are so arranged as to give that contrast of reddish pink and white so eminently characteristic of tangled tufts of coralline. The body is very small, with a pale ground colour and crimson markings; there are no gills, but the back bears five to seven pairs of very large papillæ, each of which is covered with large tubercles, whose crimson colour stands out against the light tint of the papillæ. The papillæ are often described as resembling pine cones, and their shape and markings give them an apparent bulk out of all proportion to the size of the body. In confinement they are very apt to fall off at the slightest touch. The tentacles are very slender and spring from large trumpet-shaped sheaths. The animal lives on zoophytes and is strictly an inhabitant of deep water. I do not know the special value

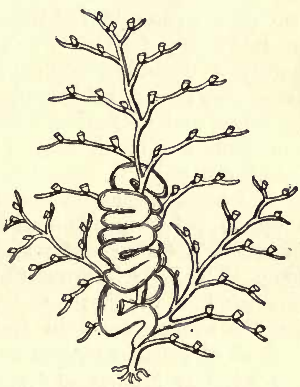

Fig. 75.—Spawn of *Doto coronata*. After Alder and Hancock.

of the resemblance to coralline, nor do I know what animals attack it under natural conditions.

The next set of sea-slugs we shall consider belong to the very large genus *Eolis* (see Fig. 76), whose members often chiefly differ from one another in colouring, and are usually exceedingly beautiful. All are characterised by the simple slender papillæ arranged in rows or clusters at the sides of the back. Most of them live among weeds and zoophytes, on the latter of which they chiefly feed. We shall consider here only a few of the commoner species.

The common grey sea-slug (*Eolis papillosa*) is the largest of our species, and may reach a length of three inches, but is usually much smaller. The middle of the back is perfectly smooth, and in small, delicate specimens it is easy to see the beating of the transparent heart through the skin. The sides of the body are densely clothed with closely set papillæ, arranged in more or less distinct rows, and usually greenish or brown in colour. As in the other species there are two pairs of tentacles—a dorsal pair, here short and stout, and a ventral or oral pair beside the mouth. The colours are variable, but usually not bright, and the papillæ so frequently fall off in confinement that the animal is hardly a desirable occupant of an aquarium. From its large size it can be dissected more readily than many of its allies, and dissection will disclose the curious fact that the stomach is much branched, its branches being continued into the papillæ.

The next species is much more beautiful, and is fairly common between tide-marks on the North-east Coast. It is called *Eolis coronata*, and is usually less than an inch long. The body is proportionately much more slender and elongated than that of the preceding species, and the papillæ are arranged in transverse rows across the back instead of in dense masses at the sides. The dorsal tentacles are what is known as "coronated," being surrounded by spiral yellow projections of very characteristic appearance. The oral tentacles are very long and slender, and the anterior angles of the foot are produced. The body is a delicate pinkish white colour, but it is to the papillæ that the animal owes its beauty. They are transparent, and traversed through the greater part of their length by the branches of the stomach, the result being that each is bright crimson in colour, tipped with white above the point where the branches of the stomach stop. In another light, however, the crimson part suddenly flashes out into the brightest blue optical colour, with a sheen like that of a bird's feather. In certain lights the little animal closely resembles coralline, while in others the blue tints make it stand out vividly. It is a most beautiful little species, and lives well in confinement. I have found it not infrequently at low spring tides.

The next species—*Eolis rufibranchialis*—may justly be described as quite common, at any rate in the Firth of Forth, where I have found numbers of specimens. It generally resembles the preceding species, except that the

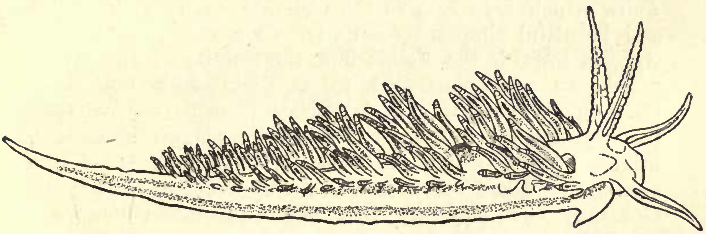

FIG. 76.—*Eolis rufibranchialis.* Note the processes, or papillæ, on the back, the two pairs of tentacles, and the minute eyes at the base of the upper tentacles. After Alder and Hancock.

dorsal tentacles are transversely wrinkled, instead of distinctly coronated, and the papillæ bright red in colour, with a white ring near the tips, and no trace of metallic sheen. The body is white. This is a very hardy species, and active in confinement. The general characters may be easily made out from the figure.

There are a great many other species of *Eolis* on our shores, but those named are the commonest, and may serve to give an idea of the general structure and habits. Those who desire to pursue their observations further should consult the beautiful *Monograph of the British Nudibranchiate Mollusca*, by Messrs. Alder and Hancock, or attempt to make a journey to the Newcastle Museum to see the original drawings of the last-named, which are among the treasures of the collection there.

The sea-slugs are in many ways a most interesting group, and well worth careful attention. First as to structure. With the exception of *Aplysia*, all those we have named are without trace of shell; but this is not universally true of Opisthobranchs, for some of them have well-developed shells. The shell has indeed been gradually lost, as in so many groups of Mollusca. Then, again, the sea-hare has a typical gill like that of whelk or periwinkle; *Doris* has a circlet of many gill-plumes, and these gradually decrease in number as in *Polycera* and *Ancula*, till we come to forms with no gills at all. Simultaneously with the disappearance of the gills we have the appearance and increase of the curious papillæ, branched as in *Dendronotus*, or simple as in *Eolis*, which help to give the Opisthobranchs their quaint and beautiful shapes. Similarly, we see in passing from *Aplysia* towards the Eolids how the solidity of appearance which we are accustomed to associate with our shore Gasteropods gives way to a delicate translucency or transparency, and the dull tints of whelk or periwinkle to soft, bright colours, which are sometimes like those of the surroundings, and sometimes markedly different from these. Generally, we may say that the Opisthobranchs are a specialised group of Gasteropods, which in some cases have lost many of the Gasteropod characters, but which can be shown to have originated from typical forms with coiled shell, visceral hump, gill, and characteristic asymmetry.

KEY FOR IDENTIFICATION OF ANIMALS DESCRIBED IN THIS CHAPTER.

OPISTHOBRANCHS. Usually without shell, gill behind the heart.

(1) Shell present, one lateral gill.

Shell concealed, delicate, single gill, 2 well-developed epipodia .	*Aplysia hybrida.*

(2) Shell absent, gills plumose, placed round anus in mid-dorsal line.

Body ovate, depressed, mantle large, without processes, covering head and foot, dorsal tentacles retractile . .	*Doris* . .	*D. tuberculata*, 9 tripinnate gills, tubercles numerous, round. *D. johnstoni*, 15 tripinnate gills, tubercles minute, close-set. *D. repanda*, 5 tripinnate gills, tubercles small, distant. *D. bilamellata*, numerous simply pinnate non-retractile gills, tubercles large, unequal. *D. pilosa*, 7 to 9 non-retractile gills, mantle with dense soft papillæ.
Body elongated, mantle small, without processes, not covering head and foot, dorsal tentacles non-retractile	*Goniodoris* .	*G. nodosa*, gills 13, simply pinnate.
Body elongated, mantle small, bearing lateral processes, gills 3, tripinnate . . .	*Triopa claviger.*	
Body elongated, mantle indistinct, head with 4 to 6 processes, gills 7 to 9 with lateral appendage at each side .	*Polycera quadrilineata.*	
Like *Polycera* but without head appendages, except for 2 on the tentacles, and with only 3 gills surrounded by processes . . .	*Ancula cristata.*	

(3) Gills absent, processes numerous, simple or branched, tentacles with sheaths.

Body narrow elongated, processes numerous branched, tentacles with branched sheaths	*Dendronotus arborescens.*	
Body narrow and small, processes unbranched, large and massive, tentacles in plain sheaths	*Doto* . .	*D. coronata*, processes with 5 to 6 rows of tubercles and a terminal one.

(4) Gills absent, processes linear or fusiform placed along sides of back, tentacles 4 without sheaths.

Body elongated, tapering behind with numerous simple papillæ or processes . . .	*Eolis* . .	*E. papillosa*, 18 to 24 transverse rows of papillæ, body broad. *E. coronata*, papillæ in 6 to 7 clusters at each side, dorsal tentacles coronated. *E. rufibranchialis*, dorsal tentacles wrinkled, papillæ red in 6 to 7 clusters.

OUTLINE CLASSIFICATION OF GASTEROPODS.

I. The Chitons, primitive forms very different from ordinary Gasteropods.

II. Zygobranchs, limpet-like forms.

III. Azygobranchs, forms with coiled shell, single gill in front of heart.

(*a*) Forms with unnotched shells, such as the periwinkles, the tops, and others.

(*b*) Forms with notched shells, such as the whelks, dog-whelks, and others.

IV. Opisthobranchs, forms often without shell, gill behind the heart.

(*a*) Forms with shells (Tectibranchs). Of these only the sea-hare has been described.

(*b*) Forms without shells (Nudibranchs), the different kinds of sea-slugs.

NOTE ON DISTRIBUTION.

The sea-hare is commoner in the South than in the North, and is said to be especially abundant at Weymouth and Torbay. Of the remaining sea-slugs described in this chapter, certainly the majority occur all round the coast, though their relative abundance varies greatly. In the West and South-west—as indeed everywhere to a greater or less extent—other species occur between tide-marks, but the forms mentioned may be sufficient to afford an insight into the chief modifications of external form in the Nudibranchs. Certain of the species of *Doris* are especially widely distributed and common. I have found singularly fine specimens of *D. tuberculata* in abundance between tide-marks, at such widely separated localities as Alnmouth and Aberystwyth. Many of the Nudibranchs, indeed, seem to be as universally distributed around our coasts as such familiar forms as the common shore crab, the mussel, cockle, shrimp, periwinkle, but in most cases the sea-slugs are less likely to be noticed than these.

CHAPTER XIV.

BIVALVES AND CUTTLES.

General characters of Bivalves—Their classification—The saddle-oyster and the mussels—Their structure and habits—Oysters, Pectens, and Lima—Swimming power of Pecten and Lima—Characters of Cyprina—Mactra and its allies—The Venus and carpet-shells—The cockles—The gapers—Mya and Lutraria—Rock-borers—The cuttles.

THE next great group of the Molluscs is constituted by the Bivalves, or Lamellibranchs ("plate-like gills"), of which the oyster, mussel, and clam are familiar examples. In order to get a notion of the anatomy, it is well to obtain a living mussel and a living example of the bivalve known as the little carpet-shell (*Tapes pullastra*), which is very abundant on the rocks. The blue shells of the former, and the brownish yellow ones of the latter, are very common objects on most shores. Place both in water, and notice the two valves of the shell, united to one another by an area of greater or less extent known as the hinge. Notice that when the animals are at rest the valves gape slightly, allowing certain of the soft parts to protrude. But when alarmed they close their shells suddenly, sometimes sending out a sudden jet of water in the process. The way in which the shell is closed enables you to conclude at once that it must be the result of muscular action; there are, in fact, large closing muscles, usually two in number, in all Bivalves, and they are very characteristic structures.

Next study carefully the parts protruded in an open bivalve. Take the mussel first (see Fig. 77). As the shell gapes there appears at the part of the shell opposite the hinge a fringed mantle-flap (*i* in Fig. 77), which is double in correspondence with the shell whose valves it lines. At the straighter side of the shell there is protruded a slender white foot (*f* in Fig. 77), by means of which the animal slowly moves. If allowed to remain undisturbed it ultimately anchors itself by a rope of threads, or byssus (*b* in Fig. 77), secreted from the foot, and serving to fasten the animal to the surrounding stones or shells. The byssus is rapidly formed, and can soon be renewed if torn away. At the side of the shell opposite to the foot it will be seen that the two parts of the mantle are fused together at two places a little distant from one another, so that a very short tube (*e* in Fig. 77) is formed. By placing the mussel in slightly turbid water, it is easy to see that in life there is a continuous current of water *entering* by a wide space between the halves of the mantle marked *i* in Fig. 77, and *leaving* by this short tube, which constitutes the *exhalent aperture.* The lower current brings with it food particles and the oxygen necessary for respiration, the upper current carries out the waste carbonic acid and the indigestible residue of the food.

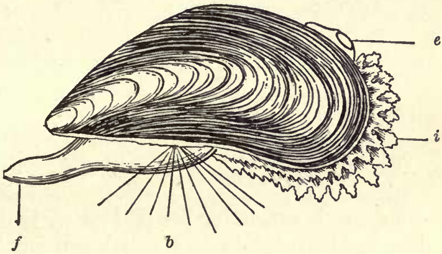

FIG. 77.—Edible mussel (*Mytilus edulis*). For letters see text.

Turn next to the little *Tapes*, and you will find very similar conditions, save that the foot is of a different shape, and the two apertures are drawn out into long siphons or tubes, which can be protruded or retracted, and whose tips are beautifully fringed. A little observation will show that by the upper of these the water escapes, while it enters by the lower. Again, while the mussel must live freely exposed to the water, the carpet-shell, on account of its siphons, is enabled to live buried in sand or mud with merely the siphons protruding. Before proceeding to remove the upper valve of your specimens to examine the anatomy, study some empty shells of the same or different species. In the mussel notice first that the two valves of the shell are of the same size (equivalve); this is very characteristic of Bivalves, and, together with the fact that each valve is inequilateral, is a convenient means of distinguishing them from Brachiopods, or lamp-shells, which have inequivalve but equilateral shells. In other words, the shell of a bivalve is divided into two equal parts when the valves are separated, but not when the valves are divided by a median line. The shell of a Brachiopod, on the other hand, consisting as it does of two valves of unequal size, is divided into two equal parts only by a line which bisects the two closed valves.

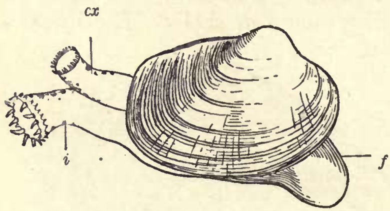

FIG. 78.—*Tapes pullastra.* *f*, foot; *i*, inhalent siphon; *ex*, exhalent siphon.

Again, the two valves of the shell of the mussel are united at the hinge by an internal cartilage called the ligament, so placed as to cause the shell to gape, except when it is forcibly closed by muscles. The hinge is overhung by two projections, or beaks, which form the oldest part of the shell. In the inside of the shell are to be seen markings indicating the places where the muscles of the shell have been attached. In the mussel these are two in number, and are placed at the side of the shell opposite to that where the foot is protruded. In addition to these markings, there is an uninterrupted line near the margin of the shell which marks the line of attachment of the mantle to the shell. If the mussel shell be compared with that of *Tapes*, it will be seen that in the latter case this line of attachment does not follow uninterruptedly the margin of the shell, but is at one spot inflected to form a deep, rounded bay, called the pallial sinus. This sinus marks the attachment of the muscles which move the siphons, and its presence in a shell enables one to conclude at once that the living animal possessed siphons.

The shell of *Tapes* differs in several other respects from that of *Mytilus.* Thus the hinge, instead of being smooth, is furnished in each valve with three projections, or teeth, which lock into corresponding cavities, in much the same way as that in which the bones of the skull in a mammal are locked together. Further, the ligament in *Tapes* is outside the shell, instead of being within it, and the two muscle impressions are more distinctly marked than in the mussel.

Having by the study of the shell determined the position of the closing muscles, kill your living specimens by dropping them in hot water, slip a knife in between the valves, and cut through the muscles as close to the shell as possible. As soon as this is done, the elasticity of the ligament will cause the shell to gape, and the upper valve can be gently removed. If this be done carefully in both mussel and *Tapes*, the animal in each case will be seen lying covered by its mantle-flap, with the foot projecting more or less at one end, and the apertures, or siphons, distinct at the other. There is no head, but the mouth is placed at the opposite end to the apertures, or siphons, and usually lies at the more rounded end of the shell. It is immediately in front of the foot, and has two little flaps, or *palps*, at either side. On lifting up the mantle there will be found the plate-like gills, of which a pair lie at either side of the foot. Projecting through the softer tissues will be also seen the firm closing muscles cut through when the shell was opened, and the foot, small in the mussel but large and distinct in *Tapes*, as in most common Bivalves.

We cannot enter in detail into the anatomy of the Bivalves—they are difficult to dissect and to understand—but it may be well to explain briefly what structures vary most frequently, and on what the usual classifications are based. In the first place, there is much and very obvious variation in the shell, in its shape, colour, and finer details. Almost all early classifications depended on the shell. But we have seen that the shell affords clear evidence as to one structural characteristic of the living animal, the absence or presence of siphons, so that a very early division is that into siphonate and asiphonate forms. Again, in some cases, as in *Tapes*, there are two distinct closing muscles, while in others one only is present. As this character can also be determined by the examination of the shell, it is very frequently used in the classification of Bivalves. Finally, the gills vary much in structure, being sometimes composed of free filaments, and at others woven into more or less compact, plate-like structures. We shall adopt here a classification based on this difference in the gills, for the following reason. There can be no doubt that the existing Bivalves have been derived from forms similar to, but simpler than, the less specialised of existing Gasteropods. The early Bivalves must have had simple, plume-like gills, similar to the gills of many Gasteropods, and the more complicated the gills of present Bivalves, the further have they departed from this primitive condition. The most natural classification seems, therefore, one based on the gills. As, however, we shall consider only such Bivalves as are likely to be found in the living condition, or are very abundant in the dry condition on the shore, we shall consider only three orders: (1) the Filibranchs, those with filamentous (or thread-like) gills such as the common mussel; (2) the Pseudo-lamellibranchs, those like the scallops, which have gills apparently of plate-like structure, but with the separate filaments so slightly attached that they fall apart very readily; (3) the Eulamellibranchs, the great majority of Bivalves in which the gills are firm plates, whose constituent filaments cannot be readily separated from one another.

The first order includes the curious little saddle-oyster and the mussels, together with other forms which need not be considered here. The saddle-oyster, or silver-shell (*Anomia ephippium*), is common under stones between tide-marks, and exhibits several peculiarities of structure. The shell is fragile, pearly white in colour, and often irregular in shape. It consists of an upper convex valve, and a lower flat one perforated by a large hole beneath the beaks. The animals are extremely sedentary in their habits, growing fixed to rocks, but the fixation is accomplished in a somewhat peculiar way. We have already explained that most Bivalves possess a byssus gland in the foot, which secretes a mass of silky threads serving to anchor the animal to surrounding objects. The saddle-oyster also possesses this characteristic gland, but both it and the foot are much reduced and apparently functionless. But nevertheless the animal does fix itself firmly to rocks, and it is of interest to notice how it accomplishes this. Of the two adductor or closing muscles which most Bivalves possess, one is here very rudimentary, while the other is large and conspicuous. From this large muscle a slip arises which passes through the hole in the lower valve of the shell, and is attached to the rock. Its end is furnished with a curious limy disc or operculum, formed by an aggregation of many little plates. In the living animal the shell, as usual, gapes to allow for the entrance of the necessary currents of water, and there is also, owing to the relaxed condition of the attaching muscle, a space between the lower valve and the rock. When the animal is alarmed the muscle contracts suddenly, the result being not only to close the valves, but also to drag the lower valve close against the rock. You will appreciate the meaning of this best by trying to peel the animals off the rock with your fingers, after they have been thoroughly alarmed. The method of attachment is very interesting, and offers some curious problems in origins to those speculatively inclined. Why should the saddle-oyster have given up its original method of attaching itself by a byssus? And if its peculiar method is advantageous, why should other sedentary forms have not adopted it? There are many similar questions which one may ask, though I do not know if they can be answered at present.

Saddle-oysters are very abundant on the shore, but on the East are usually of small size, the shells being often under half an inch in diameter. From their habit of closely accommodating their shells to the irregularities of the rock surface, they are very apt to be overlooked by careless observers.

We come next to the mussels, familiar forms, unfortunately burdened with a plethora of names. We shall describe three species, placed in as many different genera, viz. the edible mussel (*Mytilus edulis*), the horse-mussel (*Modiola modiolus*), and the marbled Crenella (*Crenella marmorata*). All three are nearly related, and are sometimes placed in the same genus, or given other generic names. All are common, and may easily be found in the living state.

The edible mussel is easily recognised, and has already been in large part described. It occurs in small numbers on most parts of the coast, but in favourable situations forms great mussel beds which are often carefully preserved, and are of considerable commercial value. Before the mussels can multiply with sufficient rapidity to form these beds, they must have abundant food and a suitable substratum. For food they seem to depend largely on the finer refuse brought down by rivers, and they rarely flourish except where food of this kind is abundant. Where it is abundant, however, they occur in numbers which are literally countless, as everyone who has seen a healthy mussel bed must know. In one respect such beds are peculiarly deceptive, as the unwary naturalist is likely to speedily discover. My own first introduction took place in the Firth of Forth, where a very low tide had laid bare a long stretch of thickly covered rocks, dotted here and there with huge starfish. Mindful of the tide, I hastened outwards with more speed than discretion, and, planting a hasty foot on a patch of mussels, found that it sank downwards over the boot-top in a mass of fine mud before it reached the firm rock. Later I learnt that this mud may reach a depth of many feet; so that it is distinctly unwise to rashly undertake the investigation of mussel beds. What happens is this—the mussels attach themselves to a smooth rock, and by means of the fine cilia (whip-like threads) on the surface of the gills and mantle produce rapid inhalent currents. If the water contains many suitable solid particles they flourish apace, digesting these, and passing out the indigestible residue in the form of fine mud. This mud accumulates rapidly and would soon stifle the mussels, were it not that as it is deposited they gradually lengthen their attaching threads, so that they rise above the surface of the rock. In still water the process may go on until the byssus threads reach a length of several feet, the space between the shell-fish and the rock being occupied by a mass of solid mud. The result is that although a flourishing mussel bed may be both useful and valuable, it is neither pretty nor sweet-scented.

The large horse-mussel does not, strictly speaking, live on the shore rocks, but young forms are common there, and the shells of the adult are not infrequently found on the sands.

The shell is larger and stouter than that of the edible mussel, and may be distinguished from the latter by the fact that the beaks are not terminal, but slightly to one side. The colour is very dark blue, almost black, and the shell is covered by a translucent membrane, or epidermis, which in the young is prolonged into a fringe. The byssus is very strong, and the animal entangles with it shells and small stones, so as to form a kind of nest. It lives usually in sand or mud in comparatively shallow water.

The third mussel is a much prettier species, whose habitat renders it peculiarly interesting. The edible mussel spins a rope by which it fastens itself to stones or posts, the horse-mussel uses its threads to weave foreign objects into a protective nest, but *Crenella marmorata* finds shelter and safety within the tests, or outer coats, of sea-squirts (Ascidians). Into these it burrows deeply, so deeply that its presence can only be discerned by the resistance which the Ascidians offer to the touch. Ascidians of various kinds are common on most shores, often growing in masses beneath overhanging rocks. Frequently, also, they are torn up by gales, and strewn in repulsive-looking masses along the shore. If your ardour is not quenched by an unfavourable exterior, and is sufficient to lead you to tear open the tough cases, you are likely to find not only the curious Ascidians themselves, but also one or two specimens of the pretty green *Crenella marmorata*. It also occasionally occurs in nests like those of *Modiola modiolus* made of shells or stones. The shape is very characteristic, the shell being markedly gibbous, or swollen, and rhomboidal in shape. It is sculptured by fifteen to eighteen longitudinal ribs anteriorly, and by twenty to twenty-five posteriorly, the ribbed areas being separated by a smooth region. The beaks are small, swollen, inflected, and divergent. The foot is white and very long, and is used in leisurely progression, as well as in secreting the byssus threads.

In the next order, the Pseudo-lamellibranchia, are included some exceedingly beautiful forms—indeed, I have heard it maintained that one of them, *Lima hians*, is the most beautiful of our common marine animals. Others of them, such as certain of the scallops, have always been prized by shell collectors for the bright colouring of their shells, which are usually marked in shades of red and pink. We shall consider in the order only three genera—*Pecten*, *Lima*, and *Ostrea*—all characterised by the structure of the gills, the absence of siphons, the single adductor muscle, and some other common characters.

Of the scallops the most abundant is the common scallop (*Pecten opercularis*), often seen in fishmongers' shops in the larger towns. There are few stretches of sandy shore where the separate valves of this species are not to be found, but living animals are not quite so easily obtained. Those sent to market are obtained by dredging, but where, as in the Forth, there are large scallop beds, it is quite common to find small living specimens on the shore rocks. After storms, also, living scallops are often cast up in large numbers on the shore, or are found living in the rock pools. Such specimens are often somewhat injured by their journey, and rarely live long in confinement, but small specimens from the rocks live well, and form charming pets. Select a few specimens about the size of a penny-piece, and carry them home to your aquarium, or domicile them in some rock pool. While you are admiring the beautifully sculptured and coloured shell, its valves will suddenly gape, and from the semicircular space so produced long, white threads will be protruded, which float freely in the water. Watch the opening shell carefully, taking care that your shadow does not fall on the water, and you will see that the two fringed mantle-folds are set round with—jewels I would say, did not strict accuracy compel me to call them simple eyes. But jewels they are, nevertheless, if changing tint, with gleam of emerald and amethyst, may earn the name. It would not be easy to say how much the scallop really sees with them, but it is certain that it very speedily becomes aware of differences in the intensity of light, or of rapid movement. When it is alarmed in this way, it suddenly changes its position by flapping its valves together in a way which drives it through the water in a series of rapid jerks. This power of swimming is very characteristic of the scallops, and is a very curious sight. As they rest in the bottom of the pool or dish, they look as passive as any other bivalve, and when without apparent stimulus of any kind these passive shells suddenly spring upwards in the water, and by a succession of movements drive themselves a very considerable distance through it, the astonished onlooker is apt to receive something of a shock. It should be noted that the movement is not accomplished by the foot—the characteristic organ of locomotion in the Mollusca—but by shell and mantle. Nevertheless, just as *Anomia* has a small attaching byssus, although it attaches itself by another and quite different organ, so the scallop has a foot, although it is not used in locomotion. When your little scallops lie motionless at the bottom of the dish, you may see the slender, finger-like foot protruded at one side. It is capable of spinning a slender byssus, by means of which the animal, especially when young, temporarily anchors itself.

When you have studied the living animal, and watched its curious flight, you should collect a goodly number of shells from the shore and proceed to study them in detail. It is well to have a considerable number of specimens, for there is a large amount of variation, especially in colour—indeed, there are said to be no less than six colour varieties in the Firth of Forth alone.

If your specimens consist, as often happens, of detached valves, you should first pick out and distinguish the upper and lower valves. Both valves are convex, but one is more convex than the other, and in natural conditions it is the less convex which is the upper. The difference between the two valves is, however, not marked, and the shell is therefore described as sub-equivalve—that is, with nearly equal valves. It is also almost circular (sub-orbicular) and almost equilateral. Like that of all other *Pectens*, or scallops, it is furnished with two ears, here almost equal in size, and has a straight hinge line with a marginal ligament, and a central cartilage placed in a pit beneath the beak of each valve. The special characteristics of the species are found in the number of the ribs (about twenty) and the peculiar structure of the surface of the shell. It is covered with close rows of minute scales, which require some little attention before they can be seen, but once the shell has been closely studied it is almost impossible afterwards to mistake the species for any other. In the commonest colour variety the shell is red-brown marked and spotted with white.

The common scallop is not the only edible species of *Pecten*, for the much larger *P. maximus*, often called a clam, is not infrequently seen exposed for sale. It is a very handsome species, reaching a size of six by five inches, and often of a pale colour beautifully mottled with pink. The valves are very unequal, the lower being deeply convex and the upper almost flat, except for a slight concavity near the beak; it is always much darker in tint than the lower valve. The convex lower valve bears fourteen to sixteen broad, rounded ribs, wider than the spaces between them. In the upper valve the relation of ribs and spaces is reversed, so that the two valves lock closely together, a condition which may be noticed in many Bivalves. The ears are nearly equal, but are concave in the upper valve and convex in the lower. The surface of the shell is quite without the scales of the preceding species, but is marked by distinct radiating striæ, which with the broad ribs are very characteristic of the species. Separate valves of this species are not uncommon on the shore, but I have never found the entire animal, either living or dead. Specimens for dissection may be obtained at times from the fishermen. The shells are sometimes used by cooks, and are very commonly sold in fishmongers' shops at a penny apiece, but unfortunately it is usually only the convex lower valves which can be obtained in this way.

We shall mention one other species only, one which is interesting because, like the oyster, it is fixed when adult, and, as in the oyster, the shell is often curiously distorted. This is *P. pusio*, odd valves of which may be often found on the shore. The animal is attached by the lower valve, which is usually white, without sculpture, and often of very irregular shape. The upper valve has its surface covered with very numerous (40–80) prickly ribs, often alternately large and small. In the young the ears are unequal in size, and in the adult they become very irregular.

The next genus is the very beautiful one of *Lima*, of which we shall consider one species only—the delicately tinted *L. hians*. Strictly speaking it is beyond our range, but is such an interesting and beautiful species, and so common in the Clyde, that we must make an exception in its favour. In it the shell is snowy white, and the mantle a lovely pink. It swims in a way which casts the efforts of the scallops into the shade, and as it jerks rapidly through the water it trails behind it a long mantle-fringe of rosy pink, forming altogether a picture which once seen is not easily forgotten. My own first experience of it was a memorable one. It was on my first dredging expedition, and the scene was the broad waters of the Clyde. The wind blew strong and fresh, dashing the salt spray over the side of the little yacht, as she heeled under the pressure of her heavy dredge; but it was not strong enough to damp the ardour of the enthusiasts, who clung desperately to any available rope in their anxiety lest some treasure should escape their notice. There were many treasures in the heavy net, but perhaps the greatest were the rough-looking masses of stones, shells, and weeds fastened together by byssus threads, which we were told were the nests of *Lima*. When carefully broken, these nests disclosed the animal itself lying snugly in the centre. They were dropped into jars of clean water, and instantly began to swim rapidly, trailing their beautiful fringes behind them. They would be beautiful in any situation, but seen against a background of blue hills, with the fresh breeze in one's face, the blue waters around, and the rocking boat beneath, there was certainly an added charm. For my own part I cannot think that a thousand daffodils can be so fair a sight as half a dozen *Limas*, let the yellow bells dance never so merrily. The memory of that first day has at least made the animals particularly dear to me.

This particular species, *L. hians*, does not occur on the East Coast, so a journey must be made to the West to find it. The shell shows much general resemblance to a scallop, but is longer in proportion to its breadth, and has less prominent ears than most scallops. The shell gapes at both sides, and is marked by numerous fine radiating lines, crossed by other concentric lines. The animal also shows much resemblance to a scallop, but its tentacles are much longer and more numerous, and the curious habit of nest-building also affords a contrast. Except in the extreme South the animal is confined to deep water.

The third genus of the order, that of the oyster, is of more interest to the epicure than the shore naturalist. The edible oyster (*Ostrea edulis*) is related to the scallops, but differs in its peculiarly sedentary habit with which is associated the distorted and ugly shell, in the entire absence of foot and byssus, and in some other characters. Just as many domestic animals acquire their culinary value at the expense of almost all the qualities which make them interesting to the naturalist, so the oyster pays for its valued qualities by the absence of the beautiful shell, the power of active locomotion, the quick senses, and the other qualities which make the *Pectens* and *Limas* so fascinating. Those who are not epicures may perhaps be forgiven for regarding a luscious oyster as about as attractive as a prize pig, while those to whom it appeals as an article of diet will probably mourn with the famous conchologist that oysters grew and died in countless numbers before ever men existed to enjoy them. There can be no difficulty in recognising an oyster if one should be found, which is not very likely. The chief point of interest is the curious shapes which the shells assume when subjected to pressure by surrounding objects. The animals are incapable of locomotion, and are attached by the surface of the lower valve, for the byssus gland has been completely lost.

The third order of Bivalves, the Eulamellibranchia, includes the greater number of living forms. Its members are classified according to the presence or absence of the siphons, the amount of union of the mantle-folds, the characters of the gills, and some other points. Most of them live buried in sand or mud, and the development of siphons is an adaptation to this habit. Their degree of development is reflected in the shell in the condition of the pallial sinus (see p. 268), and where, as in the *Myas*, they reach a great size, they cannot be completely withdrawn into the shell, and this "gapes" permanently. From the habitat—usually sand or mud—these Bivalves are rarely conspicuous on the shore rocks; many may be obtained by systematic digging near low-tide mark, others are tossed on the beach after storms, but the majority, even of the shallow-water forms, are familiar only in the condition of shells. As our concern here is rather with living animals than with "shells," we shall describe relatively few Bivalves, chiefly those which may be hoped for in the living condition.

As an example of one of the simplest Eulamellibranchs we may take *Cyprina islandica* (see Fig. 79), which is often very abundant in the living condition after storms. It has practically no siphons, the mantle-folds are widely open, and the pallial line is simple, without trace of sinus. The shells are large, triangular, and convex; they are sometimes used as scoops, and called "sugar-shells." The surface of the shell displays admirably a structure which we have not yet expressly noted, and that is the layer called by conchologists the epidermis. The shell of a Mollusc is made of three layers, an external organic layer without lime, the epidermis, a prismatic layer forming the bulk of the shell, and an internal pearly layer, often absent, but sometimes very well developed. In many shells the epidermis is early rubbed off, exposing the prismatic layer, which is often brightly coloured externally; but in *Cyprina* it is thick and persistent, giving the shell its characteristic brown colour. The shell is heavy and massive, obliquely triangular, and swollen towards the beaks. It is marked by numerous fine concentric lines, and is covered by the brown epidermis. The teeth are well developed, there being three cardinals, or central teeth, in each valve, and a single lateral. The interior of the shell is smooth and chalky white. This combination of characters makes the species readily recognisable. The animal lives in muddy sand, in which it burrows by means of the large foot. It is sometimes used as bait.

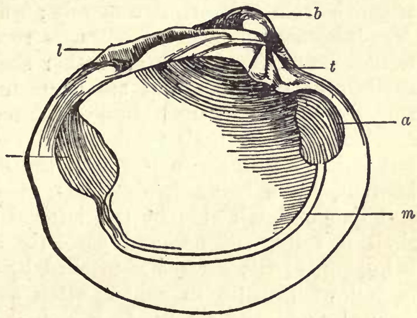

FIG. 79.—Left valve of shell of *Cyprina islandica*, to show markings of interior. *b*, beak of shell; *t*, one of teeth; *a*, anterior adductor muscle; *p*, posterior adductor; *l*, ligament; *m*, mantle-line.

In the next sub-order, which includes such important genera as *Mactra*, *Tellina*, and *Donax*, the siphons are long and the pallial sinus deep. Of the three genera named, the species of *Mactra* are most commonly found in the living condition, and are also very common as shells on the beach at all seasons. Two of the species, *M. solida* and *M. subtruncata*, are very much alike, and not easy to distinguish from a description merely; while the third species, *M. stultorum*, or Fool's Mactra, is readily recognised, and cannot be confused with any other shell. In all cases the shells are triangular, and are characterised by the almost smooth surface and the nature of the teeth. Of these there are two thin cardinals in the right valve, and two similar but united cardinals in the left; the laterals are large and laminar, there being two on each side in the right valve and one on each side in the left. In *Mactra solida* the shell is solid, opaque, and perfectly triangular, the sides being equal; the surface is marked by concentric striæ and is yellowish white in colour, often stained by substances derived from the sand. It is not easy to point out distinguishing differences from *M. subtruncata*, but the latter is smaller, more convex, and seems to be hollowed out at either side of the beaks, so that these become more prominent. In *M. stultorum* the shell has the same shape as in *M. solida*, but is thin, delicate, glossy, and almost smooth. The colour is a pale brownish tint, variegated by longitudinal rays of reddish brown. The shell is very familiar, and is represented in all the collections of children; the other species, on the other hand, being thick and clumsy, are often neglected.

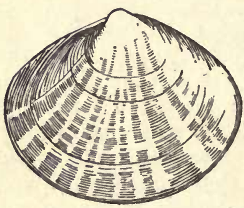

FIG. 80.—*Mactra stultorum.*

As members of the same sub-order we may mention two other forms, abundant as shells, but not commonly found in the fresh condition. One of these is *Donax vittatus*, the purple toothed-shell, an active little form which lives in sand near low-tide mark, whose shells are greatly prized by children both for their beauty and colour varieties. The living animal is both interesting and beautiful, the foot being large in proportion to the body, the mantle delicately fringed, and the siphons, which are quite separate, marked with longitudinal lines and delicately fringed at the tip. The shell is small, at most an inch long, and some half-inch broad. It is oblong and beautifully glossy and polished, the surface being marked by fine longitudinal striæ. The inner margin is strongly notched, and the inside of the shell is usually stained with violet. The colours of the outer surface are varied, usually shades of violet, brown, or yellow, but it is sometimes almost white.

An even prettier and more delicate shell is the little *Tellina tenuis*, which, thin and fragile as it is, is often tossed up intact after a storm. The shell is often pure rose-pink, sometimes pure white, sometimes yellow or orange. It is so much flattened that one might fancy the animal would hardly have room to live inside, and so thin that it can hardly afford much protection. The ligament is very thick and prominent, the teeth small. The shell is oval and semi-transparent. There are various other species of *Tellina*, some of them common but mostly small, and not to be found in the living state.

Another sub-order includes the *Venus* and carpet-shells, of which there are a number of species. The species of *Venus* are very numerous, and can be recognised by their triangular or rounded shells with distinct concentric ribs. It may, however, be sufficient if we name one species, common at all seasons as a shell on the shore, and to be found living in sandy places. This is *Venus striatula*, a small shell measuring about an inch each way. The animal has fairly long siphons united for the greater part of their length, a thick foot slightly bent, and mantle-folds open in front. The shell is pale-coloured, but usually marked by three bright-coloured longitudinal rays of reddish tint, which cross the strongly marked concentric ribs. A point of interest about the animal is that it seems to be greatly relished as food by some of the whelks, for most of the shells found on the shore are perforated near the beak, showing that the whelk has drilled a hole through it, as a preparation to the devouring of the contained animal.

Of the little carpet-shell (*Tapes pullastra*) we have already spoken; it occurs very commonly on the rocks in sandy and muddy places. The shell is rhomboid in shape and solid in texture; it is marked by very numerous close-set bands crossed by fine longitudinal striæ. The colour is yellowish white, variegated with reddish brown. There are three cardinal teeth in each valve. A prettier species with more distinctly marked ribs, and streaks and patches of bright colour, often occurs on the shore in the dead condition. This is *T. virgineus*, which inhabits somewhat deeper water than the common species. The latter lives well in confinement, and affords an admirable object for the study of the siphons. When alarmed, the animal suddenly retracts these, producing a very forcible jet of water as it does so; when it is lying undisturbed the course of the breathing currents can be clearly seen, especially in water containing suspended particles.

The next sub-order includes the cockles, which have a greatly elongated foot, used in taking "leaps," and also in burrowing in the sand. There are a considerable number of cockles, but as the differences between the species are not very well marked, it may be sufficient if we describe the common, or edible cockle (*Cardium edule*). This species, as is well known, occurs in beds in sandy and muddy ground, living on, or only slightly below, the surface. It is valued both as food and bait, and is collected by the fisher folk in large quantities, short rakes being used for the purpose. The shell is equivalve, somewhat triangular, and strongly convex. The characteristic cockle appearance is produced by the sculpture, which consists of twenty-four to twenty-eight flattened ribs separated by narrow furrows. These ribs project at the margin, as in all cockles, so that the valves lock closely together; in the living animal the mantle is fringed with delicate processes corresponding to these ribs. In an empty shell the internal characters can be made out, the fluted margin, the muscle scars, the strong central (cardinal) tooth in each valve, shaped like a reversed V, and the small laterals at each side of this. The different cockles are distinguished chiefly by the sculpture of the shells, and the number and shape of the ribs; generally speaking all are readily recognised as cockles.

We come next to two genera whose members show some marked resemblances, combined with distinct differences. In both the large siphons cannot be completely retracted, so that the shell "gapes" permanently, and cannot be closed.

The first genus—the old maid shells, or *Myas*—includes two common species which live buried in sand near low-water mark, and often occur in large numbers on the beach after storms; the empty shells are to be found at all seasons. In both the siphons are large, invested in a common sheath, and united throughout their length. The shell is oval or oblong, and gapes at both ends. The hinge-cartilage is wholly internal, and is placed between a cavity in the right valve and a hollow in a conspicuous process of the left valve. The internal position of the cartilage and the presence of the large cartilage in the left valve make the shell of a *Mya* easily recognised. The shells are solid, opaque, not glossy, and with little brightness of tint. The

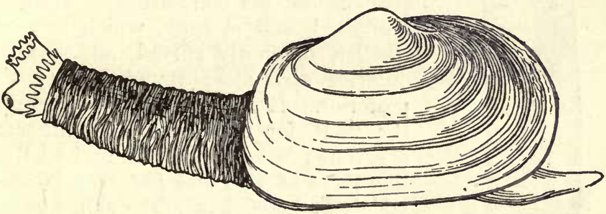

FIG. 81.—*Mya truncata*, showing siphons and foot.

two species are *Mya arenaria* and *Mya truncata*, chiefly distinguished by the shape of the shells. In *M. arenaria* this is oblong, and about twice as long as broad; in *M. truncata* it is oval, and the length bears to the breadth about the proportion of five to four. In the latter, further, the posterior end of the shell is abruptly truncated; in the former it is wedge-shaped. Both are used as food and bait, and are greatly relished by seagulls, who may be found feasting on them after storms.

The other genus includes the otter-shells (*Lutraria*), of which we have one common species, *L. elliptica*, which inhabits the same localities as the *Myas*, and is to be found with these after storms on the shore. The siphons are very long, and are inclosed in a common sheath, but are not completely united. As in *Mya*, the shell gapes at both ends, but it is much thinner, and is glossy and brightly coloured. The shape is elliptical and compressed, the cartilage internal placed in a deep pit, the teeth consist of two diverging cardinals in each valve and two rudimentary laterals.

We come next to the razor-shells, or *Solens*, interesting Bivalves which cannot be confused with any others, and which are very common, though not often seen in the living state. They live near low-water mark, where they burrow deeply in the sand, but may be readily dug out by an expert digger. We have two common species—*Solen siliqua* (see Fig. 82), the common "razor-fish," in which the shell is almost straight and the ends are both abruptly truncated, and *S. ensis*, which is much smaller, distinctly curved, and has the anterior end more rounded than the posterior. It is unnecessary to describe the shell, for this must be familiar to everyone; but it should be noticed that, like those of *Mya* and *Lutraria*, it gapes widely at both ends. The shape of the foot is interesting, and its efficiency as a burrowing agent should be noted on the shore; it will be noticed that its general appearance varies much, according as it is in action or at rest. It protrudes from the anterior extremity of the shell, and the united siphons from the posterior. When the animal is undisturbed these are protruded at the surface, and have the usual functions.

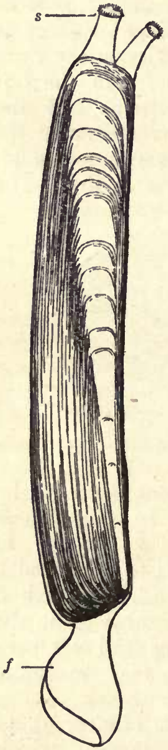

FIG. 82.—Razor-shell (*Solen siliqua*). *f*, foot; at the other end the siphons (*s*) are visible.

The two last Bivalves we shall consider make their homes not in sand or mud, but in rocks, into which they burrow deeply. These are *Saxicava rugosa* and the species of *Pholas*. The first is abundant everywhere, wherever suitable rocks occur. It is common in limestone, which is often literally honeycombed by its burrows. The blocks are thus rendered less resistant to wave-action, and are torn off from the solid mass of rock. They are then often utilised in rockeries, and on the East Coast it is common to find these built of such honeycombed stones still retaining the little shells. In the living condition the animal is very common on the shore, where its bright red siphons are to be seen protruding from rock surfaces. When touched they eject a forcible jet of water and then disappear. By breaking the rock, specimens can be obtained without difficulty, the shells though small being solid and not readily broken. They are oval in shape and gape at the posterior end; the colour is white, and the shells generally without much beauty. It seems unnecessary to describe the details, as the bright red siphons and the habitat form very distinctive characters.

Even more interesting are the species of *Pholas*, which have singularly beautiful shells. One species, *P. crispata*, is exceedingly common in the Firth of Forth, where it excavates the shale in all directions. Some of its characters have already been noticed in Chapter I., so we may confine ourselves here to some details of the shell. As in all species, this gapes widely both in front and behind; there is no ligament nor teeth, but there is an accessory valve, or dorsal shield, beside the hinge; the hinge-plate is reflected over the beaks, and the shell is divided into nearly equal parts by a broad oblique furrow. Of the two regions so formed the anterior is furnished with about twenty rows of overlapping prickles, supposed to be of great importance in boring; the posterior region is quite small. The whole shell is pure white and very brittle, so that a little care is necessary to obtain uninjured specimens. Another species, *P. candida*, also occurs in shale, but may be distinguished by the absence of the furrow, the prickles covering the whole surface except a space at each end.

We have now mentioned most of the Bivalves likely to be found living between tide-marks. Of the Mollusca there still remain the Cephalopoda, or Cuttles, specialised forms in which the foot has grown up round the head and become split into eight or ten sucker-bearing arms. Other characteristic structures are the funnel, through which jets of water can be ejected, thus producing motion, and the ink-bag, whose contents produce a dark cloud in the water. The cuttles are powerful animals and active swimmers; except at the breeding season they are rare between tide-marks. In the early months of the year a large form, *Ommastrephes todarus*, is common on the beach after storms on the East Coast, but this is due to the fact that at this time the animals come shorewards to lay their eggs. The spawn, both of this form and of *Loligo vulgaris*, is not uncommon. The former consists of somewhat pear-shaped masses, each containing many eggs embedded in jelly and fastened in dense clusters to weed. In the latter case the eggs are arranged in long tubes, which are similarly attached in clusters to weed. The animals are, further, at times represented by their "pens," which are internal structures corresponding to the "bone" of the squid (*Sepia*), and probably to the last remnant of the shell which the early cuttles possessed. The pens of *Loligo* and *Ommastrephes* are horny structures, not unlike a quill pen, and reaching a length of a foot or more.

In a living cuttle the beautiful changing tints should be noticed, the arms and suckers, the jets of water which are ejected from the funnel, and in natural conditions drive the animal backwards, the fins fringing the body, and the large eyes. A dead specimen will show the strong parrot beaks within the mouth, the gills within the mantle-chamber, and the ink-bag. The special characters of *Ommastrephes todarus* are as follows: The fins are placed at the posterior end of the body; the two long arms are nearly as long as the body; the eight short arms have two rows of suckers; the cornea, or transparent skin over the eye, has a central hole, so that the sea-water gains access to the anterior chamber of the eye. The animals reach a length of over a foot. Between tide-marks in the South a pretty little octopus, or form with eight arms, is at times to be found. This is *Eledone cirrosus*, a very charming little creature. On the shores of the English Channel the common octopus (*Octopus vulgaris*) is at times abundant in the vicinity of the shore.

KEY FOR IDENTIFICATION OF COMMON BIVALVES.

BIVALVES, or LAMELLIBRANCHS.

(1) Filibranchs, with filamentous or thread-like gills.

Shell of irregular shape, lower valve with aperture .	Surface scaly, without ribs	*Anomia ephippium.*
Shell equivalve, oval or oblong, beaks incurved, hinge without teeth .	Shell wedge - shaped, beaks terminal, colour blue	*Mytilus edulis.*
	Shell oblong, swollen in front, beaks anterior, colour dark purple .	*Modiola modiolus.*
	Shell short and tumid, partly ribbed and partly smooth, colour greenish yellow . . .	*Crenella marmorata.*

(2) Pseudo - lamellibranchs, gill-filaments only slightly attached together.

Shell suborbicular, inequivalve, marked with ribs, beaks with distinct ears, shell not gaping, brightly coloured . . .	*Pecten* .	Ribs 20, surface with minute scales—*P. opercularis.* Ribs 14 to 16, surface with radiating striæ—*P. maximus.* Ribs 40 to 60, prickly on upper valve only — *P. pusio.*
Shell like the above, but gaping, colour white, valves equal . . .	*Lima* .	Shell oblique, gaping widely at both sides—*L. hians.*
Shell irregular, inequivalve, upper valve flat and lower concave, teeth absent .	*Ostrea* .	Shell round in young, and later becoming irregular —*O. edulis.*

(3) Eulamellibranchs, gills plate-like, the filaments firmly attached together.

(*a*) Shell closed.

Shell oval, with distinct epidermis and external ligament, no pallial sinus	*Cyprina* .	Shell obliquely triangular, swollen towards beaks—*C. islandica.*
Shell triangularly oval, slightly striated, with deep sinus, cartilage internal . . .	*Mactra* .	Shell solid and opaque, triangular—*M. solida.* Similar, but smaller, more convex, and with more prominent beaks — *M. subtruncata.* Shell thin, glossy, with brownish rays—*M. stultorum.*

Shell wedge-shaped, smooth, glossy, with external ligament and deep sinus . . .	*Donax* .	Margin strongly notched, interior stained with purple—*D. vittatus.*
Shell compressed, rounded in front, angular and slightly folded behind, ligament external, prominent	*Tellina* .	Shell thin, glossy, semi-transparent—*T. tenuis.*
Shell rounded, solid, with concentric ribs and small sinus	*Venus* .	Shell triangular, inside margin notched, except at posterior side—*V. striatula.*
Shell oblong, beaks anterior, margin smooth, sinus deep and rounded.	*Tapes* .	Shell solid and opaque, marked by numerous fine concentric bands—*T. pullastra.*
Shell convex, triangular, with radiating ribs, notched margin and fluted interior. Beaks prominent, incurved .	*Cardium* .	Ribs 24 to 28, furrows narrow—*C. edule.*
(*b*) Shells gaping.		
Shell oblong, valves unequal, left valve the smaller, with large cartilage process . . .	*Mya* .	Shell oblong, twice as long as broad—*M. arenaria.* Shell oval, abruptly truncated behind—*M. truncata.*
Shell oblong, two diverging cardinals in each valve .	*Lutraria* .	Shell compressed, elliptical, brightly coloured—*L. elliptica.*
Shell elongated, cylindrical, margins parallel . .	*Solen* .	Shell straight—*S. siliqua.* Shell curved—*S. ensis.*
Shell rhomboidal, wrinkled, truncated . . .	*Saxicava* .	Shell small, about 1 inch long—*S. rugosa.*
Shell white, opaque, with rows of prickles, accessory valves or shields present	*Pholas* .	Shells divided by furrow, 20 rows of prickles on anterior side—*P. crispata.* Shell not divided, 25 to 30 rows of prickles—*P. candida.*

NOTE ON DISTRIBUTION.

The Bivalves described in this chapter are, generally speaking, those which may be expected to occur at all parts of our coast, so that little can profitably be said as regards distribution. It is obvious that such forms as the edible mussel and cockle cannot from their habits be expected to occur, in any abundance at least, except where shallow, estuarine waters are available. This is true to a less extent of other sand- or mud-inhabiting forms which are naturally rare off rocky coasts, and abundant on sandy beaches. But as sand and mud are derived from rocks, it will be found that even neighbourhoods which seem to be exclusively rocky exhibit somewhere stretches of sand haunted by the common bivalves. A good example is the long stretch of sand in the vicinity of Woolacombe, on the north coast of Devon, where are to be found quantities of shells apparently absent from the neighbouring rocky beaches. Similarly, the species of *Pholas* to be found vary with the composition of the rocks, for many species stick to one particular kind of rock. As to further detail, we may notice that *Lima hians* can only be expected between tide-marks in the extreme South, and does not occur on the East Coast. On the other hand, the brown *Cyprina islandica* is a Northern form, diminishing in abundance as one passes southward. As regards the relative abundance of the others, it should be noticed that in the vicinity of fishing-villages the abundance of the shells of a particular species on the beach depends largely on the fact that the species is used as bait. The habits of the fishermen in regard to the bait used differ much at different parts of the coast, so that a great accumulation of shells of *Cardium*, *Mactra*, *Mya*, *Cyprina*, or *Lutraria*, at different parts is not in itself a proof of the predominating abundance of the particular mollusc.

CHAPTER XV.

FISHES AND SEA-SQUIRTS.

Vertebrates and Invertebrates—Structure of a sea-squirt—Some common forms—Characters of fish—The saithe, or coal-fish—Sea-scorpions, or bull-heads—Fishing-frog—The lump-sucker and its eggs—Shanny, butter-fish, and blenny, their habits and structure—The sticklebacks—Sand-launces—Flounders, plaice, and other flat-fish.

ALL the animals we have hitherto studied have been without a backbone, or equivalent supporting-rod down the back, have had a ventral instead of a dorsal nervous system, and therefore, because of these and some other reasons, all belong to the INVERTEBRATES. The VERTEBRATES, or backboned animals, are most obviously represented on the shore rocks by the fishes, of which not a few species occur in the deeper pools. But there is in addition a group of animals which, despite appearances, have some claim to kinship with the great Vertebrate stock. These are the sea-squirts, or Tunicates, which in larval life have a more than superficial resemblance to tiny tadpoles. In adult life, on the other hand, they diverge very widely indeed from the Vertebrate ideal, being little more than sacs of jelly with a tough, transparent coat.

Tunicates are common everywhere between tide-marks, but the majority are small, so that we may have to hunt for some time before finding a specimen of suitable size for a first essay in dissection. In some shady nook, or under an overhanging rock, you may find a flat, shapeless mass, attached by one of the flat sides, and of a general greenish tint. Peel it cautiously from the stone, disregarding the sudden jet of water by which it shows resentment of the process, and place in a pool or dish. In a minute or two the shapeless creature recovers sufficiently to stretch itself out in the water, and show at one end two elongated tubes, placed close together, of which the one shows eight, and the other six, red pigment spots close to the fringed openings, which are of yellowish colour. The creature has a soft, greenish coat, sufficiently translucent to allow one to see through it the distinct muscle bands of the underlying body-wall. By means of these bands it can retract its tubes or siphons, and contract the whole body suddenly on an alarm, the test, or coat, being so soft as to offer no hindrance to the process. In this respect, *Ciona intestinalis*, as this particular Tunicate is called, differs from most of its allies, which have generally such stiff coats that their activities are limited to that sudden ejection of water which gives them their common name of sea-squirts. When not alarmed, *Ciona* lies passively at the bottom of the dish, and it can be seen that a continuous flow of water passes in by the one siphon and out by the other. With a little care the internal anatomy can be made out, the Tunicates being usually fascinating creatures to dissect. As an aid in the process, a figure is given of a Tunicate from fairly deep water, in which the coat and tissues are so transparent that the internal anatomy can be made out without dissection.

Any Tunicate has outside the body the coat, or test (*t*), made of a substance apparently identical with plant cellulose, and varying greatly in thickness, colour, and consistency. It can be very readily peeled off to show the animal within. This has a thin muscular body-wall, usually traversed by a network of slender muscular fibres, which in *Ciona* are collected in definite bands. The body has no definite shape; in *Ciona* it is elongated, varying in length from about two to five inches, but it is often rounded or quadrilateral. In *Ciona* the two apertures already noticed are near together, and between them there is a little yellow mass with a few radiating threads. This is all that represents the nervous system—so small and undeveloped that one can have few scruples about hurting a sea-squirt's feelings! It is hardly probable that it can ever suffer from "nerves."

Whatever the shape of the body in a Tunicate, the greater part of it is always filled up by the large branchial sac (*br*), which usually runs from the mouth or upper opening to the other extremity of the body. It is a beautiful structure made up of bars crossing one another at right angles, the rectangles so formed being filled up by smaller bars with slits between them. The whole sac is thus a sieve, but a sieve of beautiful and elaborate structure. To the exterior this sieve opens by the mouth (*m*), and in life a continuous stream of water passes into it, then through the slits into the space between branchial sac and body-wall, and out by the lower (atrial, *at*) opening which communicates with this space. As the current passes through the slits of the branchial sac it washes the blood contained in the bars, which are really blood-vessels. The current is thus primarily respiratory, but it brings with it also the minute particles on which the sea-squirt feeds. These particles would be swept out with the water of respiration if there was not some special mechanism to retain them. The mechanism is of somewhat complex nature, and consists of two parts. To understand their position we must first determine the orientation of the body. We have noticed already the little nerve mass lying between the apertures; now development shows that this lies on the dorsal surface, and therefore that the short region between the apertures corresponds to the back of a fish, while the opposite edge is the equivalent of the ventral or under surface of the fish. Along the ventral surface of the branchial sac, then, lies a groove, the endostyle; while dorsally there is in *Ciona* a series of processes called languets. The grooved endostyle secretes sticky mucus, in which the food particles are entangled, and they are then swept backwards apparently by the aid of the languets into a slit-like opening at the posterior end of the branchial sac. This opens into the stomach (*st*), the stomach into a

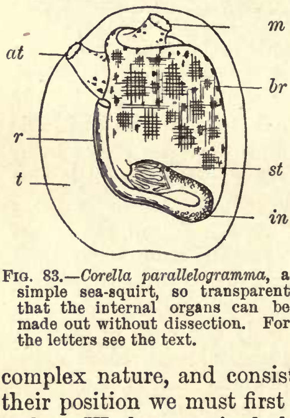

FIG. 83.—*Corella parallelogramma*, a simple sea-squirt, so transparent that the internal organs can be made out without dissection. For the letters see the text.

coiled intestine (*in*), this into a rectum (*r*), which runs forward to end within the lip of the atrial opening.

This description may sound a little complicated, but with the help of the diagram there should be no difficulty in following it. Let us summarise the salient points. A sea-squirt may be compared to what chemists call a two-necked flask, or, as the more familiar object, to a narrow-mouthed coffee-pot. Within the mouth of the coffee-pot let us suspend a muslin bag, which may represent the branchial sac. At the bottom of the muslin bag let us make a slit, and fasten to the outer side of the slit a **U**-shaped tube, so that one of the arms of the **U** reaches up to the spout, and its base to the bottom of the jug. We have then a pretty close model of a sea-squirt, but to complete the resemblance we must suppose that the muslin is covered with fine hairs, which continually bale the water through its holes. Now pour in water containing coffee-grounds, and we find that owing to the hairs (cilia) on the walls of the bag, a current is created which drives the water through the bag, and ultimately out by the spout. But owing to the arrangement of groove and processes already mentioned the coffee-grounds are, on the other hand, swept into the slit and so into the **U** tube.

The muslin bag is the branchial sac, the mouth of the coffee-pot corresponds to the mouth of the sea-squirt, the **U** tube to the alimentary canal, the spout to the atrial opening. The water, which is swept through the muslin bag to ultimately gush out at the spout, is the water which is used in respiration, for as it passes through the slits it washes the blood contained on their walls, and so purifies the blood. The coffee-grounds correspond to the food particles which are sifted out from the water, and pass from branchial sac to stomach. Here they are digested, while the indigestible residue passes into the rectum, and so to the lip of the atrial opening. The matter is of course not quite so simple as this analogy would suggest, especially in that in most Tunicates the branchial sac is so large that it has, as it were, squeezed the alimentary canal to one side, and the relation of the parts becomes in consequence somewhat complicated. But the coffee-pot model indicates the gist of the matter.

One interesting point is that, as the description shows, the branchial sac has a double function, being both respiratory and nutritive, and that through it there constantly flows a food- and oxygen-bearing current. This fact is known and appreciated by a little water-flea, or Copepod (*Notodelphys ascidicola*), which takes up its abode within the branchial sac of various sea-squirts. It is hardly a parasite, for it does not seem to injure the sea-squirt, but seeks and obtains shelter, as well as abundant oxygen and food from the incoming current. The habit might be described as a first essay towards the adoption of the parasitic mode of life, for it is probable enough that many parasites began by merely seeking shelter. Such a method of life is not peculiar to Copepods, for there are also fish which similarly seek shelter within the cavities of sea-anemones and sea-cucumbers, and the interesting case of the crab and the mussel has been already noticed (p. 202). In all such cases the cavity used for shelter must be one in which there is an abundant supply of sea-water periodically renewed, by means of which the messmate can both breathe and feed.

A considerable number of simple sea-squirts—as opposed to those forms which produce colonies—are to be found on the shore rocks, so that we can pick out one or two only. Perhaps the commonest in most places is the "gooseberry" sea-squirt (*Styelopsis grossularia*), to be found on rock surfaces as a little bright red body, often so covered with mud that nothing but the two bright red orifices is to be seen. When touched these disappear in the surrounding mud after squirting out a sudden jet of water. With a little care it is possible to remove a few specimens without injury, and make out something of the internal anatomy. It will be found that the body is nearly spherical, and the two apertures are placed close together, and are both four-lobed. If with a pair of scissors you clip the animal in two, you will see that the branchial sac has one deep fold in it, as well as some other indistinct ones, and that the inner surface of the body-wall has, on its surface, little scattered masses ("polycarps"), which are the reproductive organs, and are confined to the right side of the body-wall. These points are worthy of notice, because they serve as distinctions from *Polycarpa rustica*, another common red Ascidian, which has four folds in the branchial sac at each side, and has reproductive organs on both sides of the body-wall.

The "gooseberry" is very common, and from its tough, leathery coat it is easy to cut into sections, which show the anatomy clearly. By taking a pair of scissors, and clipping a few specimens up at different angles and in various planes, the structure can be more readily understood than by even a very careful dissection of a soft form like *Ciona*. As to the humanitarian aspect of the matter, it is difficult to think that one can have more scruples than about slicing a cabbage, but a tender conscience may be appeased by immersing the specimens for a short time in methylated spirit, and this will also assist the subsequent examination by hardening the tissues.

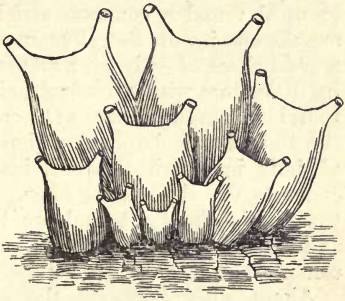

FIG. 84.—*Polycarpa rustica*, a common sea-squirt.

Besides *Ciona intestinalis*, which we have already described, several species of the genus *Ascidiella* are common on the rocks. It is hardly possible to describe the specific characters without going into details which are a little beyond our reach, but we may note that a form called *A. virginea* is very abundant in the Firth of Forth, where it grows socially in dense masses attached to seaweed, or Polyzoa, and is cast on the beach after every storm. It has a delicate, transparent test, and the body-wall is often beautifully flecked with scarlet. If specimens are collected immediately after a storm, they will be found to be still alive, and the smallest of the bunch will show the beating of the heart and the movements of the currents in a very interesting way. Sea-squirts from deep water often have very delicate tests, so that the internal structure shines through clearly, but those found on the shore have usually tough, resistant coats, which conceal the underlying organs.

In addition to the simple sea-squirts there are a great number of colonial forms, in which the small individuals are embedded in a common test, a number being usually grouped round a common atrial opening. Very abundant are the species of *Botryllus*, in which the colony spreads as a great sheet of jelly over stones, the surface being studded by little stars with a central hole. Each star is a cluster of individuals grouped about the common atrial opening, while the test of the simple Ascidian is represented by the sheet of jelly in which the individuals are placed, and which connects the clusters together. The colonies, for the most part, avoid the light, and are to be found beneath stones, and under overhanging rocks, but they are usually bright in colour—purple, greenish, yellow, and red tints being common. Along with *Botryllus* the species of *Botrylloides* also occur, in which, instead of being in stars, the individuals are arranged in long, double rows, which branch and anastomose in a complicated fashion. The colonies form their incrustations on the rocks just as *Botryllus* does, and occur in similar localities. Where representatives of these two genera occur freely, there will probably also be representatives of other genera of compound Tunicates, which in some cases, instead of being flat, form little stalked masses of jelly. They can always be recognised as Tunicates by the occurrence of the individuals, or zooids, embedded in a common jelly, and in many cases it is easy to pick out a zooid on a needle, and with a lens demonstrate the existence of all the parts which we discovered in the simple sea-squirt. But though the Tunicates—compound or simple—are an interesting group, we must not linger over them, for, generally speaking, they are too difficult as regards their minute structure for most amateurs, and the distinctions between even the genera rest, in most cases, on minute points.

Finally, we come to the Fishes, of which we can name only a few of those which haunt the rocks at low water. Everyone who has watched fish in their natural surroundings must have been struck with their singular beauty and grace; cold, slimy, and shapeless as they seem when dead, in life they are full of energy and vitality, as beautifully adapted to their surroundings as bird in air or mammal on land. Into the details of structure we cannot go, but almost any shore fish will serve to give you a general idea of the general characters of a fish.

In the first place, with the exception of skate or dog-fish, occasionally thrown up after storms, all our common fish belong to the bony fish, or Teleosteans, which are geologically recent animals, and display the fish-like characters in their highest degree of development. But as the fish in its highest development is, above all things, an animal adapted for life in mid-ocean, for swift movement, we must expect the forms available on the rocks to display the piscine characters in a less typical form than their brethren of the open sea. The fish which are always to be found in the rock pools are those which are specially adapted for that life, and which would be as helpless in the open sea as the strong swimmers of that open sea would be if confined in such pools by any untoward circumstance. Such shore fish, therefore, display various peculiarities of form which distinguish them from the more typical fish of the open sea, but these peculiarities are usually of the kind known as adaptive—that is to say, they occur in different fish not as the result of inheritance from a common ancestor, but as an adaptation to a common environment. Thus shore fishes are often without scales, they often have an eel-like body adapted for creeping through rock crevices, they may be flattened to enable them to pass their lives on the bottom, and so on.

Before proceeding to describe the peculiarities in detail, let us look at a typical fish, choosing a member of the great cod family, which includes many important food fishes. If you idly row about in a boat in the summer time not far from shore, or watch the streams of sea-water which ebb and flow through the deep channels of the rocks, or gaze down into the water from a pier or landing-stage, you are certain at some time to see shoals of fish of a beautiful greenish tint, which dart and wheel and turn in the water like swallows in the air, showing gleams of glistening silver at every movement. So abundant and so fearless are they that even the simple artifice of a bent pin and a piece of mussel will often produce several specimens, when employed off the edge of the rocks with an incoming tide. The humanitarian may protest against this, and exclaim that the naturalist cannot admire without seeking to destroy, but the fact remains that while you call these fish merely "fish" in the indefinite sense, you will observe but little of their habits; while if you possess yourself of a few specimens, learn their name, and something of their characters, the next time you see those shoals you will not only observe much more than you did the first time, but your interest will be greatly intensified, and your chances of seeing much greater.

There need be no difficulty as to name, for these pretty fish are saithe, or coal-fish (see Fig. 85), in the adult stage

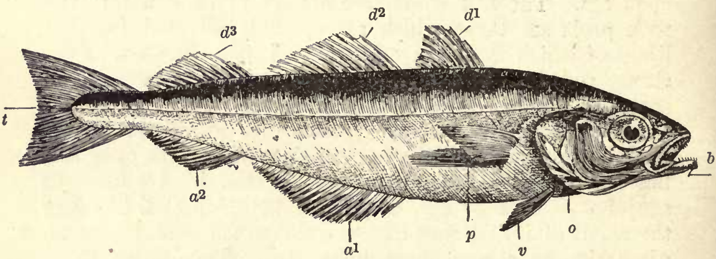

FIG. 85.—Saithe, or coal-fish (*Gadus virens*), to show typical fish-like shape. d^1, d^2, d^3, the three dorsal fins; *v*, the ventral fin of right side; *p*, the right pectoral; a^1, a^2, the two anal fins; *t*, the equally lobed tail fin; *b*, the rudimentary barbule. Note also the lateral line, and the operculum (*o*) covering the gills. After Day.

often sold to innocent housewives as cod, and in the young stage known to all boys as poddlers, or by a dozen other names beside. The adults grow to a length of two or three feet or more, but the shoals found off the rocks in summer time are usually the young, and are not more than a few inches in length.

As in most fish, the body is spindle-shaped, tapering behind so as to offer the least resistance to the water. It ends in a tail fin which is equally lobed, so that every stroke drives the animal straight through the water. This is a point of some interest, for it is only modern fish which possess tails of this kind. In the fish found as fossils in the older rocks, as well as in the living dog-fish and skate, the tail fin is unequally lobed, the upper lobe being larger than the lower. The result of this arrangement is that at each stroke the body is inclined downwards, for the larger lobe naturally gives greater impetus than the smaller. The reason for this is that those fish which have unequally lobed tails have their mouths on the under surface, and are usually ground feeders, so that each stroke drives them nearer their food, which they reach from above. Fishes with equally lobed tails, on the other hand, have terminal mouths, are swifter and more highly specialised. It should also be noted that in fish the tail is the main organ of propulsion, a fact which has resulted in various modifications of the body. One of the most interesting of these is that the internal organs have been shifted forwards, so as to leave the tail a mere mass of solid muscle. It is a familiar fact that the posterior opening of the food canal in a fish is far forward, and that the body organs, heart, alimentary organs, reproductive organs, etc., are, roughly speaking, crowded into the small space in front of this opening. On the other hand, in most vertebrates, such as frog, bird, mammal, the viscera extend to the posterior end of the body, and the limbs are the great means of propulsion. The student will find it of much interest to compare the conditions in prawn or lobster with those obtaining in a typical fish. In both cases the tail is used as an organ of propulsion, and in both cases is in consequence converted into an almost solid mass of muscle, which renders both sought after by man as food. There are, however, many interesting differences in detail in the mechanism in the two cases, and some even more interesting resemblances. Thus, in both cases the kidneys are shifted far forward into the head region. It must not, of course, be supposed that there is any relation between lobster and fish, even if the former is legally a "fish," but the two have both solved a mechanical problem after a similar fashion.

While swimming is effected in a fish by means of the tail, the necessary steering is accomplished by means of the fins. Of these there are two kinds—the paired fins corresponding to the limbs of other vertebrates; and the unpaired fins, which are to be found in the middle axis of the body, and vary much in different fish. It is especially interesting to note the position of the paired fins. As they correspond to the fore and hind limbs of a terrestrial vertebrate, one would naturally expect that the pectoral pair, which are equivalent to the fore limbs, should lie in front of the pelvic pair. This is the case in many fish, but in the cod family they have been shunted forward till they actually lie in front of the pectorals (see Fig. 85). This shifting seems to be associated with the general moving forwards of the organs of which we have already spoken. As regards the unpaired fins we have in the saithe three dorsals on the back, and two anals on the ventral surface behind the anus, in addition to the tail fin of which we have already spoken.

In regard to the other characters, the gills are of special importance. In a living fish there will be noticed a flat plate, or operculum, behind the mouth on either side, which is constantly opening and shutting. It is easy to observe that water is constantly entering by the open mouth, and leaving by the opening at the side of the throat which is disclosed when the operculum is raised. A more careful examination will show that internally the sides of the mouth are perforated (usually) by five clefts, bounded by bony arches bearing red gill-filaments. Externally these openings are not obvious, as they are covered by the operculum, beneath whose posterior margin the water taken in by the mouth escapes. As the water passes out it purifies the blood contained in the gills, so that the mouth-cavity, or pharynx, of the fish, like the pharynx of a Tunicate, has a respiratory function, as well as its nutritive one. Other important peculiarities are the teeth, not confined to the margin of the jaws, but also found on the walls of the mouth-cavity, and the "lateral line"—a series of superficial sense-organs which run down the sides of the body, forming a conspicuous black line in the haddock, a pale one in the saithe. The scales should of course also be noticed, and the flat, lidless eyes, so arranged as not to interfere with the general curve of the body, and so offer no resistance to the passage through the water. Into the anatomical details of structure we cannot go, but the external form and the movements are worth careful study, and your appreciation of the graceful movements will probably increase as you learn more of the mechanical adaptations which render them possible.

Before leaving the saithe, we may note that the most inexperienced housewife can distinguish it at a glance from the cod, by the fact that while the latter has a long process, or barbule, beneath the chin, the saithe has the merest trace of one (see Fig. 85, *b*). There are other striking differences, but this is the most readily observed, and is worth note, because if cod is not a particularly attractive article of diet, a full-grown saithe is very much less so.

Having gathered some general idea of the characters of fishes from an examination of the saithe or one of its relatives, such as the cod, haddock, or whiting, we may glance at the characters of some of the common rock-haunting forms.

Wherever the pools contain weed and stones one may be sure of finding at least one species of *Cottus*, little fish

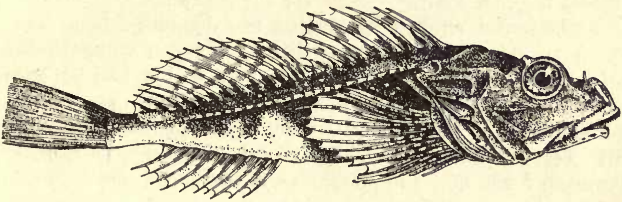

FIG. 86.– Sea-scorpion, or bullhead (*Cottus scorpius*). After Day.

belonging to the same family as the gurnet, and much feared by children on account of their spines and a tradition that they are capable of stinging. Two species are common, the sea-scorpion (see Fig. 86) and the father-lasher, or lucky proach, the former being usually from about six inches to a foot in length, and the latter usually only a few inches, though it has been found to attain a length of a foot or more. In both cases the head is broad and large, curiously disproportionate to the narrow, tapering body, and bears a very wide mouth, always eager for food. The head is flattened above, so that the eyes are in its upper surface instead of the sides, as in the saithe, and the margin of this flat head is furnished with spines borne on a plate called the preoperculum. In addition to these, other spines ornament other parts of the body, especially the head, but the skin is otherwise soft and scaleless. The gill-cover seems at first sight to be very different from that of the saithe, and is apt to be a little puzzling. If the saithe be carefully examined, it will be seen that the operculum consists of a flat hard plate, fringed at the edge with a soft membrane supported by some inconspicuous rays of cartilage, the whole lying close to the lateral body-wall. In *Cottus*, on the other hand, the soft membrane is greatly expanded, and is supported by a number of long distinct rays, curved so as to leave a considerable space between them and the underlying gills. If you seize a living *Cottus*, you will find that it is capable of greatly increasing this space by raising these rays and their membrane (the branchiostegal or gill-cover membrane), so as to greatly increase the width of the head. As the head swells the spines are erected, so as to make the *Cottus* an ugly mouthful. There can be no doubt that this must protect the fish against attack, for there are not a few stories of birds found choked by getting the distended head with its sharp spines fixed in the throat. If you compare the ugly "bullhead" with the saithe, you will notice at once how much the misshapen head takes off from the graceful fish shape, as it must also diminish the swiftness of motion, but great swiftness is probably not necessary to a rock-haunting form, and the shape fits it for a life among rocks and weed.

As to the other characters, we may notice that the pectoral fins are large and fan-like, accentuating the size of the anterior region of the body, while the ventrals are small and inconspicuous. There are two dorsals and one anal fin, and the tail fin is simply rounded and not cleft. There is no marked distinction in colour between the two forms, the general tint in both cases being brown or greyish green, prettily marked and banded with dark brown or black. In the sea-scorpion the under surface is pale, or sometimes yellow, with strong dark markings. There is no great difficulty in distinguishing the two species. In *Cottus scorpius*, the larger, the preoperculum bears two spines, the upper and longer of which is less than the diameter of the eyes; the first dorsal fin has nine to ten rays, the second thirteen to fourteen, and the anal nine to thirteen. In *Cottus bubalis* the preoperculum bears four spines, of which the uppermost and longest is longer than the diameter of the eyes, and the fin rays number as follows: first dorsal, eight; second dorsal, eleven to twelve; anal, nine. Both species often occur in the same locality, are easily caught, and, in the case of small specimens at least, live well in confinement. Very small father-lashers can easily be kept alive in a shallow pie-dish, provided they are regularly fed, for they are exceedingly voracious. Almost any small marine animal is acceptable, especially the young of other fishes, which are eagerly snapped up. In consequence of their voracity, and the ungraceful shape, the bullheads have come in for not a little abuse at the hands of even naturalists, who should be unprejudiced persons; but, nevertheless, in life in their natural environment, they certainly do not lack that adaptation to their surroundings which is the first canon of beauty, while their vivacity and activity make them most interesting pets.

The next fish we shall consider haunts in life sandy places, but is often cast up on the shore, and has such a mass of fact and fancy interwoven with it that we cannot pass it by. This is the fishing-frog, or "angler" (*Lophius piscatorius*), sometimes called the sea-devil. It grows to a huge size (six to seven feet), and is then certainly ugly enough, but very small specimens are fascinating little creatures. The head is exceedingly broad and flattened, the mouth being enormously wide and capacious. The name is derived from the fact that the first dorsal fin is represented by a series of spines, of which the first three are detached and form the "fishing-lines." The first bears a little glistening flap of skin which acts as a lure in the following way. The angler partially buries itself in the sand; the filament, which lies close above the mouth, protrudes from the sand, and its terminal plate, which can be moved by an elaborate series of muscles, quivers in the water. The result is that little fishes swim up, from curiosity or hope of food; then the great jaws open and the little fishes are seen no more. The stratagem is evidently successful, for the anglers obtain an enormous number of fishes, so many that in some places the fishermen open them for the sake of the contained prey. The anglers swim but slowly, so that they could not hope to overtake their prey by chasing them. When found thrown up on the beach the colours are striking enough, being dark above and white below; but it is said that in aquaria the fish show remarkable resemblance to the surroundings, and even when not buried are very inconspicuous. In the anterior regions especially, the sides of the body are furnished with fringed filaments, which resemble fragments of weed, and must assist the process of concealment.

Apart from the lure the angler has many striking peculiarities of form, most of which are obviously adaptations to the peculiar habit. Thus, while the pelvic fins are small and short, the pectoral are strong and remarkably modified, so that the fish can use them to progress over the bottom, or to excavate cavities in which the body may be concealed. The reason why the arm-like fins are used in creeping along the bottom, instead of the same result being produced by strokes of the tail as in most fish, is supposed to be that the former produces a silent, or rather waveless mode of progression, which is more in harmony with the habit of stalking the prey than rapid motion accompanied by disturbance of the water would be. The motion is greatly assisted by the somewhat elaborate articulation of the fins, which makes great freedom of movement possible. Again, the great mouth is furnished with numerous incurved teeth, which permit of very free entrance, but no exit. This is not always an unalloyed advantage to the angler, however, for it has been known to swallow such things as stone sinkers, cork buoys, hooked fish, and even the ends of boat-hooks or mops, and being unable to readily reject them again has been ignominiously captured. But to the tales of the power and feats of the angler there are verily no end, for its habits have always aroused intense interest from the time of Aristotle to the present day.

It is perhaps hardly necessary to describe in detail the other peculiarities of structure, for the huge head, with its dangling filaments, makes the animal easy to recognise. Its interest is that it illustrates, to an even more striking degree than the species of *Cottus*, how the typical fish-shape may be lost as an adaptation to a special mode of life.

Another interesting fish, sometimes thrown up in hundreds on the beach in spring, is *Cyclopterus lumpus*, the lump-sucker, a curious unwieldy animal, interesting on account of its habits. The young may be found in abundance in the rock pools in summer and autumn, but to get the adults one must search in the early spring months. Then, in pools through which a stream flows, you may often find a large mass of bright pink eggs, adhering to stones or weeds. Close beside it, often half uncovered at low tide, is the *male* parent, who with great devotion watches the eggs until they hatch. He is said to carry away the young with him after hatching has taken place; but I do not know how to reconcile this statement with the fact that the young are abundant in the rock pools. Of the devotion of the males, however, there can be no doubt, for they may be watched every spring, and by marking a specimen it is easy to show that the watching lasts for at least several weeks. Unfortunately, as March and April, the months in which the eggs are laid, are apt to be stormy months, the weeks of watching are not infrequently prematurely cut short by the death of the male. In both sexes there is a curious suctorial disc on the under side, by means of which the animals can attach themselves to any firm surface, but as they are feeble swimmers they are unable to resist the action of the waves when once torn from their attachment, and the males especially, from their prolonged and dangerous proximity to the shore, are peculiarly liable to destruction in high winds.

In regard to the special characters (see Fig. 7) the body is short, thickened, and elevated, and marked by strong lines of tubercles. Of these there is a prominent row along the middle of the back, which, being elevated on a crest, gives rise to the Scotch name of paddle-cock or cock-paidle (the male), and three pairs of lateral rows, in addition to numerous scattered processes. These tubercles, together with the ventral sucker (formed of the ventral fins), make it impossible to confuse the fish with any other. The colours, especially on the under surface, differ in the two sexes, for this is orange-red in the breeding male and bluish black in the female. Though its appearance is not appetising, readers of *The Antiquary* will remember that in Jonathan Oldbuck's time at least the "cock-paidle" was prized as food. It does not appear to be now commonly used in this way, but those cast on shore after the storms of spring are said to be sometimes carted away to be used as manure or for feeding pigs.

If the adults can hardly be described as graceful, the young, on the other hand, are charming little creatures, which are readily captured, live well in captivity, and make delightful pets. They differ markedly from the adults in appearance, being without tubercles, and exhibiting a singularly close resemblance to tadpoles. This is especially the case with specimens taken from dark-coloured pools, for these have the dark tint of frog tadpoles. Specimens taken from pools containing much bright weed, on the other hand, are often a fine green or olive-green tint, with conspicuous light streaks behind the eyes. They are active little creatures, darting about the water much more rapidly than the adults, but nevertheless they frequently attach themselves by the sucker, and then have a curious habit of tucking the tail round the large head. The result, when combined with

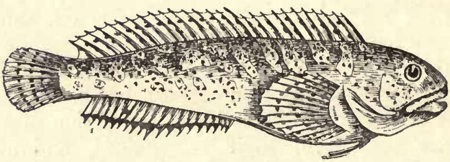

FIG. 87.—Common shanny (*Blennius pholis*). After Day.

the colour resemblance to the surroundings, is to render them very inconspicuous, and it is interesting to watch a pool with several of the little creatures darting about, and notice how they disappear suddenly from view, to be found again after careful search as apparently shapeless masses on the weed. Another interesting peculiarity is the fact that the tail fin is quite colourless, and therefore practically invisible. In consequence the dark - coloured specimens particularly seem to be sharply truncated in the posterior region, which enhances the peculiarity of the appearance.

The next fish we shall consider is the shanny (*Blennius pholis*, see Fig. 87), which may be described as a typical shore fish, for it lives in shallow pools, lurking under stones and weed, and is quite able to withstand the temporary disappearance of the water. Indeed, in confinement it seems to greatly prefer a situation where it can periodically leave the water for a time. The colours are not very definite, the body being generally greenish, marked and blotched with black, but the tints are so arranged as to correspond generally to the lights and shadows of a rock pool, and show a very considerable range of variation in harmony with changes in the surroundings. Specimens may be found of six or more inches in length, but a common size is three or four inches. Scales are absent as in most shore fishes, and the mouth is furnished with strong sharp teeth, quite capable of giving an incautious finger a sharp pinch; their function is to nip off the shell-fish, acorn-shells, and so forth on which the shanny feeds. In the related wolf-fish (*Anarrhichas lupus*), which is an inhabitant of deeper water, but is often cast ashore during storms, the teeth are exceedingly strong, and can inflict an ugly wound, but the little blenny can cause no apprehension in the case of a discreet person.

There is little difficulty in recognising so common a fish as the shanny, but the following points may be noticed. The body is compressed and somewhat elongated, and slimy to the touch; the cleft of the mouth is narrow and strongly toothed, and the anterior of the two nasal pits at each side is furnished with four or five small filaments. The fins are especially characteristic, for instead of two dorsals there is one long fin with a very distinct notch near its middle. The pectorals are large and expanded, while the ventrals are represented by two rays only; there is a long anal which, like the dorsal, does not meet the caudal. Nearly all these points are shown in the figure. A cunning and comical little fish, the shanny is well worth careful study. It has a habit of poking its head out of the water or the crevice in which it is lying, and as the lips are thick and well marked, it has then a ludicrous resemblance to a sulky, pouting schoolboy. The pectoral fins are extensively used in clambering about the rocks, the small ventrals also assisting in this process. It lives well in confinement if kept in shallow water and allowed an opportunity of leaving the water at times, and is a very favourable subject for the demonstration of colour change, as the tints vary with those of the surroundings.

Another very common fish belonging to the same family as the shanny is the gunnel, or butter-fish (*Centronotus gunnellus*), which is, however, in regard to habits at least, a less interesting creature. It has a peculiarly elongated and compressed form, is exceedingly slimy to the touch, so that though it is not particularly difficult to catch it is very difficult to retain when caught, slipping through the fingers like the proverbial eel. It is most commonly found under stones or weed, often quite out of the water, and when uncovered regains the water by very vigorous contractions of the body. Apart from the eel-like shape, it is readily recognised by a row of dark spots, usually about twelve in number, which run down the back on or close to the long uniform dorsal fin. Otherwise the colouring is not striking. The pectoral fins are not large and the ventrals very small, so that there is little to break the uniformity of the long, lank body. The anal fin is present along about the posterior half of the body. In water the gunnel swims easily and rapidly, but at low tide it is most frequently found under stones in the quiescent state. About six or seven inches is a common

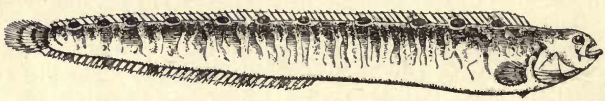

FIG. 88.—Gunnel (*Centronotus gunnellus*). After Day.

length, though larger specimens may be found, In early summer one sometimes finds the young, curious white creatures, with the heart clearly visible through the transparent body-wall.

Allied both to the gunnel and the shanny is the viviparous blenny, a comparatively large fish—it reaches a length of two feet—common between tide-marks. It is a little apt to be confused with the shanny, although when the two are put together the differences are well marked. As its name indicates, the viviparous blenny (*Zoarces viviparus*) gives birth to living young, instead of laying eggs, as the vast majority of fishes do. The young are from one to one and a half inches in length at birth, and are to be found in various stages of growth at all seasons in the rock pools, while the full-grown adults only occur there at times. Perhaps the most obvious distinction from either the shanny or the gunnel lies in the fact that the viviparous blenny has no apparent tail fin, the dorsal and anal fins merely meeting at the tapering posterior end of the body. The tails of the three forms are indeed worth careful comparison, for in the shanny the tail fin is distinctly separated from the anal and dorsal, in the gunnel these meet it, but the tail fin persists unaltered; a similar arrangement obtains in the young viviparous blenny, but as it grows older the tail fin disappears, leaving only the united dorsal and anal. In general shape the viviparous blenny may almost be said to be intermediate between the shanny and the gunnel, for it is less elongated and compressed than the latter, and more so than the former. The long dorsal fin, instead of having a notch as in the shanny, has near the tail a region containing ten spines, whose height is considerably less than that of the soft rays which support the rest of the fin. The result is to produce what is known as a "depressed" region in the fin, a very characteristic peculiarity. The anal fin is longer than in the gunnel, for it extends through about three-fifths of the body-length.

After the blennies we come to that most interesting family, the sticklebacks, which are more or less familiar to most people. In rock pools the commonest form is the fifteen-spined stickleback (*Gasterosteus spinachia*), which reaches a length of six or seven inches. In spring and early summer the pools often swarm with the young, which are most charming little creatures, and hardy in confinement, while a lucky naturalist may now and again find the nests, with the fierce father watching over the precious contents. The nests are, however, most usually in spots sheltered from violent wave-action.

There is no difficulty in recognising a specimen of the fifteen-spined stickleback, for the long snout and small mouth, the fifteen spines which represent the first dorsal fin, the row of strong plates at each side of the body, and the expanded fan-like anal, second dorsal and caudal fins, are all eminently characteristic structures. There is also something so peculiar about the way in which the little fish roots about with its long snout, and directs its tapering body in and out of the rock crevices, that one recognises it at once as different from the bullheads or blennies—the other common rock fishes. Like the other sticklebacks, it is an active and pugnacious little fish, though its habits have received less attention than the three-spined form. It does not appear to extend into fresh water, and is most abundant in pools containing much weed and stones, but I have also found it in sandy places. It will be noted that it is the male which makes the nest, and watches over the eggs, just as it is the male lump-sucker which watches over the eggs. It is true generally of bony fishes that where there is any evidence of parental care, it is the male parent which takes on this duty. The same is true of Amphibians — frogs, toads, newts, and their allies — while among mammals the care of the young usually falls to the mother alone.

In addition to the fifteen-spined stickleblack, the three-spined form (*Gasterosteus aculeatus*) does occasionally occur in rock pools, though typically a fresh-water form. It occurs not infrequently in brackish pools just at high-tide mark, especially those in the vicinity of fresh-water streams. In such pools, also, the nests may at times be found, but they are too well known to need further description. The three-spined stickleback is hardly so pretty a fish as the fifteen-spined form, for it has a more typical fish-like shape, without the long snout of the fifteen-spined form, and with three, or occasionally three or four, spines on the back instead of fifteen. Usually the fish are not more than two to three inches in length, but they are excessively pugnacious, not only fighting furiously with each other, but never hesitating to attack fish much larger than themselves. In such combats the strong spines, which they can use very effectively, form very powerful weapons, while the strong plates at the sides of the body form an efficient defence against the attacks of other fish. In the breeding season the males especially are of a brilliant orange-red beneath, the colours both there and in the other parts of the body varying in intensity according to the emotions of the fish, being brightest after victory, palest after defeat, or when the fish are under the influence of alarm. The tolerance of either fresh or salt water is remarkable, especially as there is no regular seasonal alternation between the two as in salmon or some other fish. The extraordinary variability must be associated with the power of changing the environment; but while certain varieties seem to be better adapted to life in fresh water and others to life in the sea, the capacity for change prevents the fixation of these varieties as new species.

Of the large cod family we have already described one member, and cannot devote more space to it or the related haddock, whiting, cod, pollack, etc., most of which, as strong swimmers, are more or less outside our range, though many of them may be caught off the margin of the rocks. Leaving them we may pass on to the sand-launces, or sand-eels, which may be found in immense numbers near the mouths of tidal rivers, in shallow water over a sandy bottom, or by digging in the sand. Beautiful silvery creatures they are, darting like shadows through the water, or burying themselves with swift movements in the sand. Like the young saithe, which swim in similar shoals, they are eagerly attacked by sea-gulls, as well as by predaceous fish and porpoises. On the calm summer days when the water is so still that thistle-down, blown from the neighbouring dunes, floats on its surface, and so clear that the bottom seems within the reach of the hand,—on such days one often sees flocks of screaming sea-gulls circling over discoloured patches in the water, and ever and again darting downwards to emerge with a silvery fish from the dense shoals in the water. In the same way the gulls collect about the river mouth as the tide ebbs, and seize the little fish as they swim in the shallows. That this fate may not overtake all, nature has furnished them with a protruding lower jaw, which forms an efficient shovel, by means of which the little fish may bury themselves deeply in the sand. In some places the sand-eels are caught in large numbers for bait and food by raking with hooks or rakes the loose sand in which they live; sometimes they are merely dug for like sand-worms, but, as all boys know, they may also be caught in a fine shrimping-net, or even by hook and line.

There are two common sand-eels, the greater (*Ammodytes lanceolatus*) and the lesser (*A. tobianus*, see Fig. 2), the latter being perhaps the commoner of the two. A little care is required to distinguish the two at first, but once the differences have been accurately noted the task becomes easy. As to size, the lesser sand-eel is usually only three to four inches in length, the greater about six to seven inches; but the former may reach seven inches, the latter twelve to thirteen or more. In both cases the colours are similar, being greenish above with broad lateral silvery bands and a pale under surface, but the silvery gleam is more pronounced in the smaller fish. Further, the latter in proportion to its length is more slender than the larger form, and tapers more rapidly in the anterior region. When once appreciated this is the point most useful in distinguishing the two, but till this can be done the distinction may be very readily made in the following way. Draw an imaginary vertical line from the anterior extremity of the dorsal fin to the ventral surface; in the lesser sand-eel this line will cross the backwardly-directed pectoral fin, which is elongated and pointed; in the greater sand-eel the line passes behind the pectoral fin, which is short and rounded. In both species note that there is only one dorsal and one anal fin, that ventrals are absent, the scales minute, and the whole form such as to render the action of burrowing rapid and easy. The active agent in the process, as already noted, is the protruding lower jaw, which is proportionately somewhat longer in the greater than in the lesser sand-eel.

This short list includes most of the fish common in the rock pools on the North-east Coast, but to the list may be added the flounder, as an example of the exceedingly interesting family of flat-fish, which includes in the turbot, brill, plaice, sole, and others, some of our most esteemed food-fishes. Young flounders are usually common in the rock pools, and their many peculiarities of structure render them worthy of careful study. As is obvious from their shape they are ground forms, adapted for life on the bottom. In this respect they resemble the skate and the fishing-frog, but differ from both in the way in which the adaptation is produced. In fishing-frog and skate the surface upon which the animals rest is the under surface—a condition which one would regard as the natural one; but in the flat-fish it is one of the sides. In other words, the fish are laterally compressed—squeezed, as it were, until the upper and lower surfaces have become sharp edges. Note the results of this. The pectoral fins in an ordinary fish lie at the sides of the body, therefore in the flounder we find one on the upper coloured surface and one on the lower white surface; the pelvic fins in an ordinary fish lie on the ventral (under) surface of the body, therefore in the flounder we find them both close together on that sharp edge which structurally, though not actually, is the under surface of the fish. So far all is relatively simple, but one naturally asks, What of the eyes? It is obvious that if they were to occupy the normal position we should get one on the upper pigmented surface, and one on the lower colourless surface, where, owing to the ground habitat, it would be useless. In point of fact, both eyes occur on the surface which is normally uppermost, but this is accomplished by one of the most remarkable phenomena in the development of fishes, the gradual migration of the originally lower eye to the pigmented surface. The migration occurs during the early life of the flounder, when the bones of the head are soft, and results in an extraordinary distortion of the skull. Skulls of some of the flat-fish may often be found on the shore, and should be studied with special reference to the position of the orbits. Similarly, while the young flounder has pigment on both surfaces, later the under surface (left side) becomes colourless, and the pigment is concentrated on the upper surface (right side).

In some ways one of the most interesting points about the flat-fish is the approach they make to a new type of symmetry. It is obvious that fish, like so many animals, are bilaterally symmetrical—that is, the two sides are similar to each other—mirror images of one another. But in flat-fish this similarity is no longer obvious, and the animals tend to take on a type of symmetry in which the ventral and dorsal surfaces resemble one another. Thus while in most fish the ventral fin differs in appearance from the dorsal, in the flat-fish it tends to be closely similar. Space does not, however, permit of a detailed account of the peculiarities of the flat-fish, or a discussion of the many interesting points connected with them, and the disputes to which they have given rise.

Small flounders are common in sandy pools, especially about the mouths of rivers. They may be distinguished from young plaice by the fact that the scales are rudimentary, and that there is a row of tubercles at the bases of the dorsal and ventral fins. The colour of the upper surface is remarkably like that of the sand and mud in which the fish live, whereas in the plaice it is blotched with orange spots on a brown ground; but the most obvious distinction between the young lies in the fact that the plaice has well-developed scales and the flounder only rudimentary ones. As is well known, the flounder usually lies buried in the sand, with only the mouth and protruding eyes exposed. It is very voracious and will eat almost any kind of animal food. Under the name of "flatties" flounders are often captured by boys, either by spearing or by the more primitive method of covering them with the bare feet as they lie in the shallow sandy water.

There are a considerable number of flounder-like forms, all members of the genus *Pleuronectes*, which are apt to be confused in common parlance; the name "dab" in itself and its compounds being loosely applied to several species. It is well, therefore, to expend a few pence in obtaining good-sized specimens of the flounder (*P. flesus*), the plaice (*P. platessa*), and the true dab (*P. limanda*), so as to learn once for all the notable distinctions between them. Afterwards the recognition of the young will be found easy enough.

KEY FOR IDENTIFICATION OF COMMON SHORE FISHES.

Teleosteans (bony fish, with terminal mouths and equally lobed or rounded tails).

(1) Some of the fins are at least partially supported by spines.

(*a*) Two dorsal fins, the first with weak spines. Head armed with spines .	Fam. Cottidæ.	Head broad and depressed, six rays in gill-cover membrane . .	*Cottus.*	Head spines two, shorter than breadth of eye—*C. scorpius.* Head spines four, one longer than breadth of eye—*C. bubalis.*
(*b*) First dorsal represented by isolated tentacles, or spines. Pectoral fins jointed . .	Fam. Pediculati.	Head very large, first tentacle with silvery lure, two others present, mouth very wide .		*Lophius piscatorius,* fishing-frog.
(*c*) First dorsal represented by spines, body compressed .	Fam. Gasterosteidæ.	Ventral fins, if present, consist of one spine and one ray, placed far back (abdominal) . .	*Gasterosteus.*	Two to four dorsal spines—*G. aculeatus.* Fifteen dorsal spines—*G. spinachia.*
(*d*) Dorsals occupying nearly the whole length of the back, body elongated and cylindrical .	Fam. Blenniidæ.	Single dorsal, divided into anterior spinous and posterior soft region; tail fin present .	*Blennius.*	No tentacle above the eye—*B. pholis.*
		Single dorsal, spinous throughout; tail fin present	*Centronotus*	Nine to thirteen black spots on back—*C. gunnellus.*
		Single dorsal, no tail fin, anal and dorsal meeting .	*Zoarces.*	Dorsal fin, with depressed area near end — *Z. viviparus.*
(*e*) First dorsal represented by crest, ventral sucker . .	Fam. Discoboli.	Body with rows of tubercles .		*Cyclopterus lumpus,* the lump-sucker.

(2) Fins all with soft rays.

A. Head symmetrical.

(*a*) One to three dorsal fins, ventral fins beneath throat, body elongated .	Fam. Gadidæ.	Three dorsal fins, two anals, ventrals with six rays .	*Gadus.*	Barbule rudimentary, lower jaw longer than upper, teeth uniform—*G. virens.*
(*b*) Single dorsal occupying most of back, ventrals rudimentary or absent, single anal . .	Fam. Ophidiidæ	No ventral fins, lower jaw long, anus far back . .	*Ammodytes.*	Pectoral fin long and pointed—*A. tobianus.* Pectoral fin short and rounded—*A. lanceolatus.*

B. Head unsymmetrical.

Flat-fish with both eyes on one surface, one long dorsal fin and a similar long anal . .	Fam. Pleuronectidæ.	Eyes on right side, dorsal fin begins above its eyes, two pectoral fins .	*Pleuronectes.*	Teeth lanceolate and compressed, lateral line nearly straight, scales present—*P. platessa.* Teeth conical, lateral line curved, plates at base of fin-rays, no scales—*P. flesus.*

NOTE ON DISTRIBUTION.

The fishes and sea-squirts described in this chapter are for the most part those which are widely distributed round British coasts, though in regard to fishes especially other species will be found to be common in pools on the Western coast. The curious lump-sucker is commoner on Scotch than on English coasts.

CHAPTER XVI.

THE DISTRIBUTION AND RELATIONS OF SHORE ANIMALS.

What does "littoral" mean?—Characters of the littoral fauna—The two other marine faunas—Subdivisions of the littoral zone—Distribution of British forms—The geographical regions—Origin of littoral animals—Evidence for and against a pelagic origin—Difficulties of a final decision—Relations of littoral to terrestrial and fresh-water forms—Conclusion.

WE have now completed our systematic survey of the common animals of the shore, and as we began with a preliminary study of the conditions of shore life, so it is fitting that we should, in conclusion, return to the consideration of some general points connected with the littoral fauna. In the first place, we have not as yet strictly defined the meaning of the word "shore," but have used it loosely as meaning the area between tide-marks. It is, however, fairly obvious that this area is not sharply marked off from the area just beyond low-tide mark. Very little experience in shore collecting shows that animals which in one area may be found freely on the shore rocks, in another region can only be found after storms, and thus obviously occupy deeper water. We have noticed this with regard to *Alcyonium* and the beautiful plumose anemone (*Actinoloba dianthus*), but it is true also of a great number of other forms, and has in several cases given rise to active controversies. Some particular authority gives water of a certain depth for some animal, and this is quoted by others as a final statement, and yet it is quite possible that in other localities the same animal may occur in very different depths. Indeed, it is well known that certain Echinoderms, for instance, have a very wide range in depth. Generally, we may say that in most cases depth of water does not in itself determine distribution, taking depth in this case as including only those comparatively trifling variations which occur in the vicinity of the shore, and are to be measured in unit fathoms. It may thus be asked, Is there really such a thing as littoral fauna at all, or do the familiar forms of the coast go down into the great depths? Before we answer this question, suppose we in imagination begin a series of dredgings off a rich coast, beginning operations quite near the shore in water of eight to ten fathoms, and sailing straight outwards. In our first hauls it is probable that we would get no form which was not already more or less familiar on the rocks. We would miss such shallow-water animals as the periwinkles and the shore crab, but we should probably get plenty of sea-urchins and starfish, various spider-crabs, hermit-crabs, *Galathea* and swimming-crabs, sea-firs, and so on, all animals which we know already on the rocks, though the species might be different. As we progressed outwards not a few familiar forms would disappear, and others would appear, but it is nevertheless true that we might take a series of dredgings from the East Coast of Scotland across the North Sea to the coast of Denmark, without ever losing sight of some characteristic littoral forms, especially certain Echinoderms. Further, in the course of our journey we should nowhere find a depth exceeding fifty fathoms. From these observations then we should conclude that the littoral fauna must at least extend down to fifty fathoms, though, except some of the Echinoderms, there are not very many species which can live equally well in water of a few fathoms depth and that of fifty or more.

If, on the other hand, we took our series of dredgings on the West Coast of Scotland, we should find somewhat different conditions. In the first place we should get into deep water more quickly, and in our journey westward would soon cross the fifty-fathom line. If we went onwards we should find the percentage of familiar species and familiar genera decreasing as we approached the hundred-fathom line. After this the sea-bottom slopes somewhat rapidly down to the great depths, to be measured in thousands of fathoms, whose inhabitants are usually peculiarly modified for their life in the "utter dark." Generally then we may say that the British Isles stand on a plateau bounded, except at the West, by the fifty-fathom line. The animals which live at the sea-bottom within this area—or up to the hundred-fathom line on the West—constitute the *littoral* fauna. This littoral fauna is contrasted with the *pelagic* fauna, which includes those animals adapted not for life on the sea-bottom, but for life in the open water, and with the *abyssal* fauna, which includes the animals adapted for life on the sea-bottom at great depths. Later, we shall have something to say as to the relations of these three faunas; meantime we may note that the *littoral* zoophytes bud off *pelagic* medusoids, and that most of the littoral animals (Echinoderms, Crustacea, Mollusca, etc.) have pelagic larvæ. Further, the fact that the starfish *Henricia sanguinolenta*, common between tide-marks, is to be found also at a depth of over 1,000 fathoms, shows that the littoral and abyssal faunas are not sharply marked off from one another.

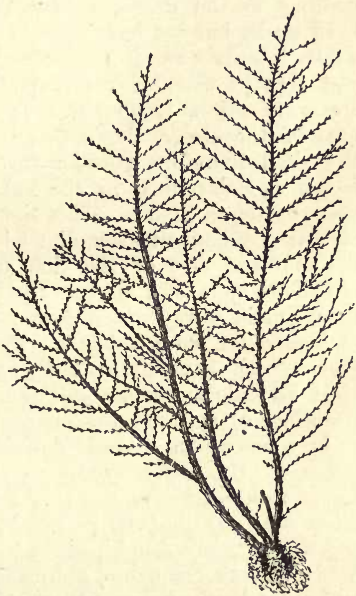

FIG. 89.—"Herring-bone coralline," or *Halecium halecinum*. After Hincks. A common littoral zoophyte.

We have thus defined the littoral fauna as including, roughly speaking, all the animals which are adapted for life on the sea-bottom in water of under 100 fathoms in depth. In many parts of our area, however, as a bathymetrical map will at once show, the greatest available depth within a reasonable distance from the shore is very much less than 100 fathoms, and usually not more than thirty to fifty fathoms, so that in most places we may say that our littoral fauna includes the animals found on the bottom in all depths from 0–30 fathoms. Even this is a considerable range of depth, and it is natural to ask whether it is not possible to divide the littoral area into zones according to the depth. Such attempts have frequently been made, but we have already emphasised the fact that depth is only one of the factors determining distribution, and perhaps not the most important factor. Other factors are wave-action, temperature, food, the salinity and clearness of the water, the nature of the bottom, and so on. We shall therefore consider certain areas of the littoral region as determined by the nature of the bottom rather than by depth alone. Thus the bottom may be rocky, a condition often well exemplified between tide-marks, where the ebb and flow of the tide and the action of the atmosphere split and fissure the rock surfaces, hollowing them out in a way which renders them eminently suitable as haunts for many animals. The rock surfaces are overgrown with luxuriant weeds, green, brown, and red. Near low-tide mark one sees the great blades of oar-weed (*Laminaria*) marking the shoreward limit of the Laminarian zone, which extends downward to a depth of fifteen fathoms. On rocky coasts one finds that the dominant forms from high-tide mark to the margin of the Laminarian zone are limpets, periwinkles, tops, dog-whelks, the shore crab, many Amphipods and other small Crustacea, the hardy smooth anemones, acorn-shells, the common starfish, and other hardy forms. In the Laminarian zone itself an enormous number of interesting and beautiful creatures occur—sea-urchins, starfish, brittle-stars, many anemones, the delicately tinted sea-slugs, spider-crabs, the edible crab, prawns and Mysids, *Galathea* and porcelain-crabs, many Annelids, and so on. Again, if the bottom be of sand or mud, instead of rocks, the great oar-weeds are replaced by sea-meadows of *Zostera*, among whose grassy blades the sea-hare, the cuttles, and many other interesting Molluscs lurk. By digging in the sand or mud one gets all those interesting creatures we have already mentioned—burrowing anemones, such as *Peachia;* burrowing Annelids, such as *Arenicola*, *Nerine*, *Glycera;* burrowing Echinoderms, such as heart-urchins and *Synapta;* burrowing Molluscs, such as *Solen*, *Mya*, *Lutraria*, and so on. About the fifteen-fathom line one comes to beds of clams, among which many kinds of animals are to be found. Beyond this depth the large seaweeds rapidly disappear, and the sea-bottom usually consists of shell-gravel, sand, or mud, each region having its peculiar fauna.

If, as we have supposed throughout this book, your observations are limited to those animals which can be obtained without a dredge, the regions which concern you are the rocks between high- and low-tide marks, the Laminarian zone, whose margin is accessible at low spring tides, and the sand or mud flats to be found especially near the mouths of rivers. We have named above the commonest inhabitants of these regions, but if we study this fauna in detail in various parts of the coast we shall find enormous variation. On parts of the East Coast the spider-crab *Hyas araneus* is extraordinarily common, on the West it is comparatively rare. In the pools on the Devonshire coast a pretty little prawn, *Hippolyte cranchii*, is very abundant, but it does not occur on the East. Throughout our study of the common animals we have constantly encountered similar facts, and frequently emphasised the differences between the fauna of the North and East and that of the South and West. Those who have interested themselves in the distribution of British plants know that somewhat similar conditions prevail with regard to them, many species being found on the West which are absent from the East. In both cases this may be in part ascribed to the difference of climate, the Gulf Stream making this much milder on the West Coast. In both cases, however, the differences cannot be wholly ascribed to differences of temperature. It is not very easy to divide the British area into geographical regions according to the distribution of the marine animals, but the following divisions at least serve to illustrate the problems involved. The German naturalist Michaelsen divides the European seas into three provinces: (1) the Arctic, including the seas north of a line drawn from the north corner of Iceland to the Lofoten

Islands on the coast of Norway; (2) the Boreal, including the seas bounded on the north by the line just given, and on the south by a line drawn above the South Coast of England; (3) the Lusitanian, including the English Channel, the Bay of Biscay, the coasts of Spain, and the Mediterranean. Thus, except the South Coast, the whole British area is within the Boreal region; but a map of the ocean currents will show that certain of these sweep our western shores, and crossing by the Shetland Isles sweep northwards along the coasts of Scandinavia. There is thus a constant tendency for the Lusitanian types to travel up along the West Coast, and such types may occur in the far North in the Shetland Islands, and again on the coast of Norway, while totally failing to establish themselves on the East Coast. Again, as there is no sharp line of demarcation between Arctic and Boreal regions, the Arctic forms tend to spread southwards, and usually find it easier to gain a foothold in the colder Eastern waters than in those of the Western coast. Thus, except in the extreme South, our marine fauna is generally of the Boreal type, but on the West there is a strong admixture of Lusitanian types, and on the East, especially the North-east, a strong admixture of Arctic types. Especially curious are the conditions in the Shetland Islands, where Arctic and Lusitanian forms intermix.

Further, as our whole area is small and the conditions fairly uniform, a dominant and successful species, whatever its original home, is likely to occur in varying numbers in all parts of our area. Thus the Norway lobster (*Nephrops norvegicus*), a typical Northern form, which is sufficiently abundant in the Firth of Forth to be the object of an important fishery, does also occur, though not in such abundance, off the South and West Coasts. The common hermit-crab of the Boreal region is *Pagurus bernhardus*, and of the Lusitanian *P. prideauxii;* but on the West Coast the two occur together in almost equal abundance. Similarly the *Stenorhynchus* of the Lusitanian region is *S. longirostris*, of the Boreal *S. phalangium;* but in the Firth of Clyde the two occur in almost equal numbers. Perhaps the prettiest example of this overlapping process, however, is the distribution of the common starfishes. The common starfish, *Asterias rubens*, is the Boreal form, and is replaced in the Lusitanian region by the spiny *A. glacialis*. The latter species is totally absent on the East Coast of England and Scotland, where *A. rubens* is abundant, often extraordinarily abundant. On the West Coast of Scotland both species occur, but *A. glacialis* is not very common. In the South-west of England both species are abundant, but east of Plymouth *A. glacialis* disappears. In this case the Lusitanian form seems to find it difficult to oust the Boreal species even in the warm waters of the West. The two forms show no very obvious differences of diet.

It is not possible to discuss in detail the distribution of British marine animals, but we may say generally that a form which occurs all round our coasts is probably a Boreal form; one which is found only on the South and West Coasts probably Lusitanian; one confined to the North and North-east probably Arctic. The study of distribution is of great interest, and it is not necessary to travel over wide areas to study it, for the differences between adjacent areas are of as much interest as those between the extreme North and extreme South, and illustrate the same problems.

The more attention you devote to problems of distribution, the more will you become impressed with the fact which we have constantly endeavoured to emphasise, that the shore is the region characterised essentially by its great variability. If you study one area for a succession of years you will notice how currents change, how deposits brought down by rivers vary in character and distribution. Closer observation is required to show that there are also gradual variations in the salinity of the water, its clearness, temperature, and so on, while the aid of the geologist must be invoked to demonstrate the fact that the land is undergoing slow oscillations of level, stable and changeless as it may seem. Now these constantly changing conditions have a most important effect upon the littoral animals, for they induce relatively rapid variation. For example, the Firth of Forth, from a multitude of causes, grows muddier year by year. We know that muddy water is fatal to many organisms, owing to its forming a deposit on their delicate breathing organs, and so asphyxiating the animals. But the danger is so common that many animals—notably crabs—have special means of filtering the water before it finds access to the gills. In crabs the filtering arrangement is obtained by spines and notches on carapace and claws, or by hairs, all structures subject to variation. In the Firth of Forth the increasing impurity of the water is certainly eliminating certain animals, as it is probably contributing to the increase of other mud-loving forms. In the case of crabs, for instance, there must be, as it were, a premium on the forms best adapted for filtering the water used in respiration, for these only can thrive and multiply. The result must be to produce relatively rapid variation, for the progeny of parents which had both an elaborate filtering apparatus will have a better chance of success than the progeny of less specialised forms, or of a mixed union. Similar variations of physical environment take place everywhere on the shore area; as the conditions change and new combinations occur, new places in nature are left vacant for progressive forms, with the result that the shore area is one where life is fast, and evolution rapid—it is not the place for decadents or survivals. It is probable that this rapid evolution has always occurred in the littoral zone, so we should expect to find that the genera and species now living in the area are modern in type, and may reasonably be regarded as having arisen within the area. But where did their progenitors come from? Has there always been an abundant fauna, or can we go back to a period when the shore waters were comparatively empty? What relation has the littoral fauna to the two other great faunas—the pelagic and the abyssal?

The answers to these questions are difficult and debated, but it may be worth while to look for a little at the matter, even if we cannot hope to reach a definite conclusion. In the first place we may clear the way a little by excluding the abyssal fauna from consideration. Its members are strangely modified animals, which, there is reason to believe, have been derived at very different periods from littoral or pelagic forms. Apart even from the fact that these deep-sea animals display many peculiarities of structure, the physical conditions which prevail in the great depths—the darkness, the absence of plants, and the consequent limitation of the food-supply, the low temperature, the high pressure, and so on—make it very improbable that the most primitive animals lived there. The problem before us, therefore, is really, Were the primitive animals littoral or pelagic? The evidence upon which the judgment must be pronounced is derived first from the geological history of animals, and second from their life-history.

What does geology teach us as to the origin and antiquity of shore animals? The earliest fauna we know is that of the Lower Cambrian rocks, and, especially in America, numerous fossils have been obtained from these beds. The fossils are, generally speaking, littoral in type, and they show that even in those far-off days the main classes of Invertebrates were distinctly marked off from one another; Cœlentera, Echinoderma, Crustacea, Mollusca, were represented then as now in the littoral waters, and their representatives showed many of the characters of the littoral forms of the present day. The presence of these numerous littoral animals in these old rocks, coupled with the paucity of pelagic forms, may seem to prove decisively the greater antiquity of the former; but the apparent strength of the argument is diminished by two considerations. In the first place, though in those old rocks there are actually imprints of jelly-fish, yet generally the animals which are abundantly represented as fossils are those only which were possessed of hard parts. Now, as we have already seen, it is characteristic of shore animals that their hard parts are well developed, while pelagic animals have usually little in the way of skeleton. The abundance of fossil littoral animals, even in very old rocks, may then be due to the fact that these are readily fossilised, rather than to their abundance relative to pelagic forms. Similarly, in the second place, those old rocks were laid down not far from land in relatively shallow water, so that littoral forms only would be likely to become entombed in sediment, and so fossilised. In general, though geology shows us that littoral animals are extraordinarily old, it virtually tells us nothing as to their age relative to other animals.

We are thus thrown back upon the evidence derived from a study of the life-history of littoral forms, but only to find that it is so ambiguous that it is capable of interpretation in two diametrically opposite ways. It may be affirmed that (1) pelagic animals have arisen from littoral ones, and (2) littoral animals from primitive pelagic forms, and both positions can be supported by an imposing array of arguments. Think of the life-histories of the littoral animals we have studied: In the Cœlentera we have often an alternation of generations, the life-history including a jelly-fish stage adapted for a pelagic habitat, and a fixed zoophyte stage adapted for life on the bottom. Among the worms there is usually a larval pelagic stage; a little top-shaped larva called a trochosphere occurs in the life-history of most of the marine bristle-worms, and is to be found near the surface of the sea. It swims by means of the motile threads, or cilia, which occur in bands on the surface of the body, and is later, by a process of metamorphosis, converted into the more or less sedentary adult. The Echinoderms, again, as we have already seen, have larvæ very different in character from the adults, and adapted for a free swimming and not a sedentary existence. We have also emphasised the occurrence of pelagic larvæ of many strange shapes among the Crustacea, and a tow-netting at almost any season of the year will show you that the surface-water simply teems with these. The Mollusca also add their quota of minute larval forms to the fauna of the open sea. Generally we may say that although there are a few exceptions, yet it is true of littoral animals as a whole that they produce minute, active, *pelagic* larvæ.

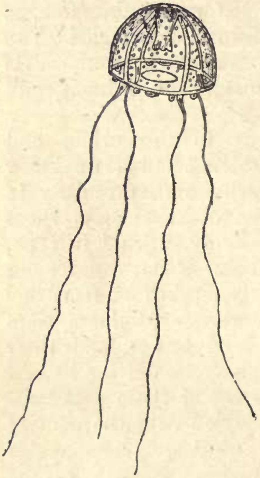

FIG. 90.—Swimming-bell, or jelly-fish stage of *Clytia johnstoni*; it should be contrasted with Fig. 6. Note short manubrium and the four tentacles. After Hincks.

Further, these larvæ are usually simple in structure, and are often devoid of those peculiarities which are diagnostic of the class to which the adult belongs; thus the very young mollusc is like a young worm, and is without such structures as shell, foot, mantle, etc., which are characteristic of the adults. Adult Echinoderms are radially symmetrical, but the larvæ are bilaterally symmetrical; we might go on to give many other examples, but these may serve to make the point clear. There can be no reasonable doubt that in some cases these simple larvæ display what has been aptly called "ancestral reminiscence"; that is, they display ancestral features, which the adults have lost. Thus the long tail of the megalopa stage of the crab shows that crabs had long-tailed ancestors; the shelled larvæ (veligers) of the common sea-slugs show that these are descended from ancestors with shells. Can we, then, say generally that the occurrence of pelagic larvæ in the life-history of littoral forms shows that these all had pelagic ancestors? It would seem that such a view had much plausibility, and yet there is a good deal to be said against it.

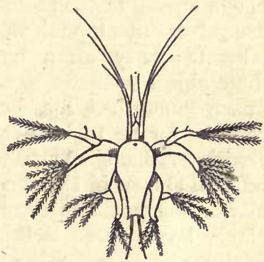

FIG. 91.—Nauplius of *Peneus*, a shrimp. The Nauplius occurs in the life-history of many shore Crustacea, and is very common at the surface of the sea. After Müller.

In the first place, when we study pelagic animals closely, we find that while they often appear at first sight to be extraordinarily simple and primitive, yet close examination shows that they must have had complex and specialised ancestors. Thus there are a great number of pelagic molluscs, often without shell, sometimes without foot or mantle, delicate and transparent in texture, simple, as one might say, in structure, and yet closer study shows that they are apparently descended from littoral forms with distinct shell, foot, and mantle. The same thing happens in other groups, and leads us to the conclusion that pelagic animals in general are often, apparently as an adaptation to their peculiar habitat, simple, delicate, and transparent creatures, but this simplicity is adaptive and not primitive.

If armed with this deduction we return to the pelagic larvæ of littoral animals, we shall find some reason to doubt our first hasty conclusion that these minute transparent creatures are really simple—really represent the primitive pelagic ancestors. The larvæ must have means of keeping themselves afloat, and these means are often wonderfully elaborate; they often have curious spines and processes, whose object seems to be to prevent them being engulfed by a narrow-mouthed foe, but which are too complicated in structure for us to believe that they could occur in a truly primitive animal. These are common in Crustacean larvæ, and well shown in the accompanying figure. Another difficulty is that in Echinoderms, where the occurrence of simple pelagic larvæ is so striking a characteristic, the larvæ of the different classes differ from one another markedly. For example, we have seen that morphologically the brittle-stars and starfishes are nearly related, but nevertheless the larvæ in the two classes show marked differences. This at once introduces a difficulty in regard to ancestry, if we suppose that the larvæ represent ancestral forms. However we regard the question it seems impossible to doubt that while the adult starfish and brittle-stars have been diverging, the larvæ have also been diverging along different lines. That is, the common ancestors of starfish and brittle-stars must have had larvæ quite different from the larvæ either of existing starfish or existing brittle-stars, and if we endeavour to discover the characters of those original larvæ by studying the common characters of starfish larva and brittle-star larva, we find that this original larva becomes pretty vague. Generally we may say that just as the apparent simplicity of pelagic animals when closely studied becomes adaptive rather than primitive, so the simplicity of the pelagic larvæ of shore animals when closely examined no longer appears to be due entirely to "ancestral reminiscence," but acquires an adaptive significance.

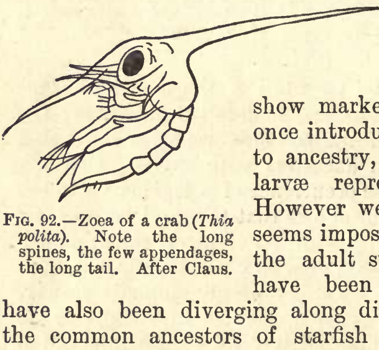

FIG. 92.—Zoea of a crab (*Thia polita*). Note the long spines, the few appendages, the long tail. After Claus.

This rather subtle argument would perhaps have little force against the theory of the pelagic origin of shore animals, if we could not give a reason why pelagic larvæ showing adaptive simplicity should occur in the life-history of shore animals. But a twofold reason is fairly obvious, and has already been suggested by implication. Shore animals usually have armour, are often sedentary, are rarely strong or swift swimmers: the minute active larvæ ensure distribution; in their own sphere they fulfil the same function as the winged seeds of our great forest trees, and their occurrence in the life-history is justified by this fact. Again, Prof. W. K. Brooks (see his *Foundations of Zoology* for details) suggests that this occurrence is also justified by the fact that life on the whole is less precarious in the open sea than near the shore. We have repeatedly emphasised the fact that in the shore waters there are multitudes of sedentary animals who live upon minute creatures found in the water, and who are constantly creating miniature whirlpools in the water as they lash it through their bodies. Against such maelströms the young forms would have no chance, so that it is safer for them to acquire more and more purely pelagic characters, and get out into the open where there are not so many hungry mouths ever ready for food.

We thus see that the arguments for the theory of the pelagic origin of littoral animals seem to be nearly balanced by the arguments against. Does the converse theory that pelagic animals originated from littoral fare any better? The theory may be put in this way. Littoral animals send off pelagic larvæ out into the open, and the specialisation of these larvæ takes place along different lines from that of the adults; the larvæ acquire elaborate mechanisms to keep themselves afloat, forms of armour which may protect them without adding greatly to the body-weight, such pale and delicate colours as may render them inconspicuous in their uniform background, and so on. Is it possible that long ago some of these larvæ forgot to grow up, if we may put the matter so, and gave rise to the original pelagic animals? Is the resemblance between pelagic animals and the pelagic larvæ of littoral animals due to the fact that the latter or similar forms were long ago the ancestors of the first, instead of to the converse relation? We shall not follow the question in further detail—perhaps to some it may seem to be identical with the momentous question whether the egg or owl came first—but enough has been said to show that the matter is worth thinking about. In closing, it may be well to note that while on the one hand there are naturalists who believe that the primitive animals were pelagic, and on the other those who believe that they were littoral, there is also a third and perhaps increasing school who hold that while existing pelagic and littoral animals are interlocked and interrelated in a thousand different ways, we have no data at present from which we can discover anything of the characters of the primitive forms. Even those, however, who believe that the open sea was the first home of life do not deny that most of the existing pelagic animals have passed through a littoral phase, and then returned to the open sea.

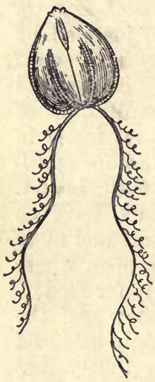

FIG. 93.—Sea-gooseberry, or *Pleurobrachia*, with the tentacles extended. A pelagic Cœlenterate with no sessile stage.

In the above discussion we have confined ourselves to the evidence derived from Invertebrates, but those who follow the argument in larger works should not forget that there is also a pelagic fish fauna, a pelagic mammalian fauna (whales, dolphins, etc.), even a pelagic insect. The last two cases show that from land and air, as well as from the shore, animals may return to the easy life of the open sea.

Littoral animals are not only interesting on account of the question of their relation to pelagic forms, for we must think also of their relation to the fresh-water and terrestrial forms. Many shore animals live near the mouths of rivers or streams, and not a few of them learn to tolerate a considerable admixture of fresh water. By some such process of gradual colonisation, we can suppose many fresh-water forms to have originated. Periwinkles and some Crustacea live at or near high-tide mark, and can tolerate free exposure to the atmosphere; it is reasonable to believe that in this way some terrestrial Molluscs and Crustacea may have arisen from littoral forms. The shore animals thus constitute a most interesting group, and have relations with most of the other great faunas of the globe.

All this may, however, be objected to as somewhat speculative, and it may be well to emphasise the practical nature of this volume by briefly mentioning, in conclusion, some possible lines of work for the shore naturalist. One would naturally seek, in the first place, to acquire a general knowledge of the common forms, and to obtain such an acquaintance with species as to give one a general idea of the meaning of specific differences, and ensure accuracy of observation—the last being a quality of somewhat slow growth. When this has been accomplished, the time for specialisation begins. Possible lines of work are many. For example, there is much to be done in regard to colour, even looked at in its most external aspect. The range of colour variation, the relation of colour to environment, and kindred problems, are still untouched in many groups. Most work in this respect has been done in Crustacea, but Echinoderms and sea-anemones may be mentioned as suitable objects for such investigations. Then the diet of many shore animals is still very imperfectly known, and much of the evidence points to the conclusion that in many cases the food varies with the locality. Where this occurs the relation of the diet to local variations in structure is obviously a point of much interest. Again, many shore animals are undoubtedly very variable, and the nature and extent of this variation offers an interesting subject for investigation. It seems probable that among the bristle-worms the range of variation is very extensive, and that systematic investigation would considerably reduce the number of so-called species. In regard to the habits of even the commonest forms much still remains to be done, and the keeping of isolated animals in confinement might yield valuable results in this respect.

But this book is primarily addressed to the many, rather than to the few who can spend much of their time in scientific pursuits, so we may perhaps, in conclusion, urge the beginner not to allow an interest in form or in "problems" to obscure an interest in animals as living creatures. It is much to learn to appreciate the charm of the crowded shore area, to see the great drama of life which unfolds itself there, as in other regions, to the patient observer, and to realise something of the unity of nature, of the order which runs through the apparent chaos of life.

SOME BOOKS OF REFERENCE.

Books marked thus * are those whose nomenclature has been employed in the text.

GENERAL.

(1) *A Manual of British Marine Zoology for the British Isles*, by P. H. Gosse. Two parts. London, 1855. Now out of print, but it may occasionally be picked up second hand. In many ways it is a most useful book.

(2) *The Marine Invertebrates and Fishes of St. Andrews*, by W. C. McIntosh. Edinburgh, 1875. Gives most useful lists, with many notes on habits, distribution, and so on.

(3) *The Marine Invertebrate Fauna of the Firth of Forth*, by Herdman and Leslie. Edinburgh, 1881. A similar work, but not quite so full.

In addition reference should be made to the works of Gosse, Lewes, Woods, and others, most of which are published under general titles. Further, the Reports of the different Biological Stations often contain important faunal lists, etc., for their special localities. See especially the *Journal of the Marine Biological Association*, published at Plymouth, and the *Reports of the Liverpool Marine Biology Committee.*

For details of structure reference should be made to the *Outlines of Zoology*, by J. A. Thomson (third edition, Edinburgh and London, 1899), or to some of the books of reference named in it. As a book of more elementary character, *An Introduction to the Study of Zoology*, by B. Lindsay (London, 1899), may be mentioned.

SPONGES.

(1) * Bowerbank's *Monograph of British Spongiadæ* (vols. i.–iv., 1864–82) is the standard work, but it may be supplemented by—

(2) *A Revision of Generic Nomenclature and Classification in Bowerbank's British Spongiadæ*, by R. Hanitsch, in *Transactions of Liverpool Biological Society*, vol. viii., 1894.

CŒLENTERA.

There is no English book dealing with the British representatives of the entire group, but certain of the sub-classes have been fully treated.

A. Hydrozoa (Sea-firs, etc.).

(1) * Hincks's *British Hydroid Zoophytes.* London, 1868.

(2) Allman's *Monograph of Gymnoblastic Tubularian Hydroids.* Ray Society, 1871–2.

(3) Forbes's *Monograph of the British Naked-eyed Medusæ.* Ray Society, 1848.

(4) For modern terminology reference may be made to E. T. Browne's *British Hydroids and Medusæ* in the *Proceedings of the Zoological Society of London*, 1896.

(5) Ellis's *Essay towards a Natural History of Corallines* (1755) is a curious old book of considerable antiquarian interest.

(6) Johnston's *History of British Zoophytes* (Edinburgh, 1838) is comprehensive as regards the ground covered, but the descriptions in most cases are too vague to be of much use.

B. Actinozoa.

(1) * Gosse's *History of the British Sea-anemones and Corals* (London, 1860) is the standard work on the subject, but for the modern names of the British sea-anemones reference should be made to—

(2) *A Revision of the British Actiniæ*, by Haddon and Shackelton, in *Transactions of the Royal Society of Dublin*, 1889 and 1891.

We are unfortunate in not possessing books which deal with the British representatives of such forms as the allies of Dead Men's Fingers (Alcyonium), Lucenaria, the large jelly-fish, the Ctenophora, and so on. Some of these are dealt with in Johnston's *British Zoophytes.*

WORMS.

(1) The volume called * *Worms, Rotifers, and Polyzoa*, in the *Cambridge Natural History* (vol. ii., 1896), by various authors, is an admirable introduction to the subject, especially as regards the Marine Bristle-worms. It contains numerous references which will enable those interested to pursue the subject further.

(2) McIntosh's *British Annelids* (Ray Society, 2 vols., 1873 and 1900) treats in detail of the British species of Nemerteans and certain families of Bristle-worms.

(3) Johnston's *British Museum Catalogue of Non-parasitical Worms* (London, 1865), though not very full, and vague in its descriptions, is helpful in some ways.

ECHINODERMA.

(1) The standard work of reference is * Jeffrey Bell's *Catalogue of British Echinoderms in the British Museum* (London, 1892), but it will probably be found difficult to use.

(2) Forbes's *British Starfishes* (London, 1841), though out of date, is well worth reading on account of the interest of the style.

CRUSTACEA.

(1) * Bell's *History of the British Stalk-eyed Crustacea* (London, 1853) is the standard work on the higher forms, but it should be supplemented by—

(2) Stebbing's *History of Crustacea.* London, 1893. International Science Series.

(3) Norman's *British Mysidæ*, a paper in the *Annals and Magazine of Natural History* (vol. x., 1893), together with some other earlier papers in the same Journal, will be found helpful, but their results are to a large extent incorporated in Stebbing's volume.

(4) For certain of the lower forms Bate and Westwood's *History of the British Sessile-eyed Crustacea* (2 vols., London, 1861–8) may be consulted.

(5) White's *Popular History of British Crustacea* (London, 1857) is a useful and comprehensive little book.

MOLLUSCA.

(1) * Forbes and Hanley's *History of British Mollusca.* 4 vols. London, 1853.

(2) Jeffrey's *British Conchology.* 3 vols. London, 1863–9.

(3) Alder and Hancock's *Monograph of British Nudibranchiate Mollusca.* Ray Society, 1845–55. All these works are well illustrated, and should be consulted, if only for the plates. There are many other works of greater or less extent on the British shell-fish, but these may serve for purposes of identification.

(4) For modern names see Norman's *Revision of British Mollusca,* in *Annals and Magazine of Natural History,* vols. v. and vi. (1890).

TUNICATA.

Although in Prof. Herdman we have an eminent British authority on this difficult group, his publications have mostly appeared in scientific journals which are not always readily accessible. Brief notes on the British species are included in **A Revised Classification of the Tunicata*, etc., published in the *Journal of the Linnean Society*, vol. xxiii., 1890; but this paper will hardly be intelligible to those who have not considerable acquaintance with Tunicate anatomy. The same author's article on *Tunicata*, in the *Encyclopædia Britannica*, republished in a volume entitled *Zoological Articles* (London, 1890), affords a valuable introduction to the subject. In Forbes and Hanley's *Mollusca* brief descriptions of the external appearance of some common sea-squirts are given.

FISHES.

(1) Day's *Fishes of Great Britain and Ireland.* 2 vols. London, 1880–4.

DISTRIBUTION, ETC.

(1) A paper on *The Fauna and Bottom-Deposits near the Thirty-Fathom Line*, etc., by E. J. Allen, in the *Journal of the Marine Biological Association* (vol. v., 1899), gives a large amount of information on the distribution of British forms, with very copious references. Many of the works cited above also include distribution.

GENERAL INDEX.

(TEXT AND ILLUSTRATIONS.)

Figures in italics refer to illustrations; those in thick type to the pages where technical terms are defined.

INDEX TO
CLASSIFICATION AND NAMES OF ANIMALS.

(TEXT AND ILLUSTRATIONS.)

Figures in italics refer to illustrations; those in thick type to the page on which the animal is described.

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