HANDBOOKS for Students and General Readers

ZOOLOGY

OF THE INVERTEBRATES

MACALISTER

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OF THE

INVERTEBRATE ANIMALS

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EXPLANATORY.

THIS Series is intended to meet the requirement of brief text-books both for schools and for adult readers who wish to review or expand their knowledge.

The grade of the books is intermediate between the so-called "primers" and the larger works professing to present quite detailed views of the respective subjects.

Such a notion as a person beyond childhood requires of some subjects, it is difficult and perhaps impossible to convey in one such volume. Therefore, occasionally a volume is given to each of the main departments into which a subject naturally falls—for instance, a volume to the Zoölogy of the vertebrates, and one to that of the invertebrates. While this arrangement supplies a compendious treatment for those who wish, it will also sometimes enable the reader interested in only a portion of the field covered by a science, to study the part he is interested in, without getting a book covering the whole.

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Care is also taken that each book admitted to the series shall either be the work of a recognized authority, or bear the unqualified approval of such. As far as practicable, authors are selected who combine knowledge of their subjects with experience in teaching them.

PREFACE.

The Student who would acquire a satisfactory knowledge of the principles of Zoology is recommended to commence by learning the elementary principles of General Biology; and having mastered these he should then study the groups of the Invertebrates as here detailed, coupling his study with a practical examination of such common types as are easily to be obtained. A jellyfish, or a hydra, an earthworm, an oyster, a snail, a cockroach and a lobster, are forms everywhere procurable, and, if examined, will give the student a good general idea of the structure of Invertebrate Animals. It must be borne in mind that without some such practical study, no amount of reading will suffice to convey accurate and adequate ideas of animal organisation.

Alexander Macalister.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

INVERTEBRATA.

CHAPTER I.

GENERAL CHARACTERS OF ANIMALS.

Physical Conditions of Life.—An animal, chemically considered, consists of a few elements[1] united into extremely unstable combinations, which are at every moment undergoing chemical change. The constituent materials are constantly becoming grouped into more simple and stable compounds, and in that state they are either eliminated or retained in an inactive condition, while other materials from without are being taken in, and so modified that they replace the molecules removed by the previous decomposition. As long as life lasts, these conditions of waste and repair continue; so that the particles of the bodies of all animals are in a state of constant change.

The food of animals contains carbon, hydrogen, nitrogen, and oxygen, which must be grouped into complex molecules before the animal can use them for his nutrition. Combinations of the requisite complexity can be derived only from previously organised

[1] Carbon, hydrogen, oxygen, and nitrogen.

materials either animal or vegetable. In most vegetables the forces concerned in assimilation are sufficient to break up originally stable compounds, such as carbonic acid, and to induce the elements to combine into the unstable combinations of which living textures consist.

The process of repair in animals has three stages, 1st, the taking in of material as food; 2nd, the changing of food into a substance capable of forming part of the living organism, *i.e.* blood; and 3rd, the laying down of this assimilated material in the tissues of the body of which it thus becomes a constituent, replacing the losses sustained by each organ in each discharge of its function.

For the life-processes of animals oxygen is necessary, and special structures, called respiratory or breathing organs, are often provided for taking it in. The carbonic acid formed from the waste of the tissues is usually got rid of by these organs.

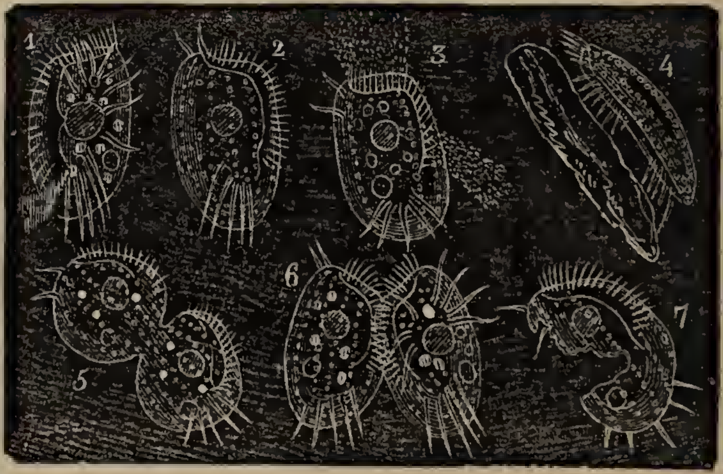
The material with which the vital properties are connected is of the same nature in all animals and is called protoplasm. The simplest animals are mere masses of this substance, which in them discharges all the functions needful for the maintenance of life; the more complex are built up of aggregations of particles of the same material, or of substances derived from it in the course of growth. Each of these constituent particles or *cells*, as they may conveniently be called, usually consists of a mass of protoplasm surrounded by an envelope of some material derived by chemical action from protoplasm. Cells continuously grouped make up tissues, and a group of tissues which performs any special duties in the life of an animal is called an organ. While there are thus varying degrees of complexity among animals, yet the parts of a simple animal have to perform as many essential functions as those of a more complex animal, the increase in complexity of an organism being correlated not with an increase in the number of essential functions but with the need for the more perfect fulfilment of existing duties. Increase in complexity thus results from division of labour, and, with each increase, the sphere of the functional activity of each part becomes narrowed. For example, in jelly-fishes one set of cavities act as organs of digestion and of circulation, while in higher animals these functions have separate organs, and even subsidiary portions of these great functions have for their accomplishment distinct parts.

Functions.—Three sets of functions are discharged by organs in the body of an animal: namely, 1st, those of Relation; 2nd, those of Nutrition; 3rd, those of Reproduction.

The organs appropriated to the functions of Relation are those which connect the animal with its environing conditions, informing it about its surroundings, and enabling it to avoid disagreeable or to court agreeable external influences. These organs are of two kinds: (A) those of sensation, such as the skin, or organ of touch, and the special sense organs (eye, ear, nose, tongue), and (B) those of motion, which may be of three kinds, (*a*) inconstant processes of protoplasm called *pseudopodia* (fig. 8), (*b*) minute, constant, hair-like processes having the power of waving to and fro, called *cilia*, or (*c*) contractile cells and fibres in bundles called *muscles*. The first kind occur in the lowest animals and in naked protoplasmic particles; the second in infusorial animals (fig. 14); the third in all but the simplest animals. Connected with the organs of relation we find a system of fine white threads called nerves, whose endings occur in these organs, and whose starting-points are central clusters of nerve-cells, called *ganglia*. These threads convey the variously received stimuli from the sense organs to the ganglia, and carry the command for motion from the ganglia to the muscles.

The function of Nutrition is discharged by four sets of organs: 1st, those of feeding, consisting of a cavity or stomach, for the reception of the food, with glands appended thereto, which secrete fluids to assist in assimilation; 2nd, organs of circulation, which carry

Fig. 1.



Euplotes Charon, a ciliated infusorium showing the stages of division.

the assimilated matter, or blood, through the body for the nutrition of the tissues; 3rd, organs of respiration, by which oxygen is taken in; and 4th, organs of excretion whereby the waste products are eliminated.

There are three stages in the contest between waste and repair which is characteristic of life. In the first, repair is in excess of waste, and individual growth proceeds until a definite limit, constant within certain bounds for each species, is reached. When this is attained, excess of nutrition still continues but tends to become separate and independent; by such discontinuous modes of growth, the third set of functions, or Reproduction, is accomplished. Of this there are three chief forms: (A) either the whole body of the parent may split into two or more, each becoming a perfect animal like its parent; this process is named *fission*. (B) In the second mode of reproduction a small portion of the body of the parent animal enlarges and becomes detached as a bud, which develops directly into an organism like its ancestor; this is called *gemmation*. (C) In the third mode small particles called eggs arise from the tissues of the parent, and on being fertilised, are capable of developing into new individuals; this is called *ovulation*.

The second stage of existence having for a time continued, the organism reaches a third stage, in which waste exceeds repair, and as, by degrees, the assimilated material becomes insufficient to keep up the processes of life this stage terminates in death.

Fig. 2.

Gemmation in the common *Hydra viridis*.

Summary.—Animals consist for the most part of protoplasm, are constantly undergoing waste, and being built up by the assimilation of food. They differ from plants in being usually capable of locomotion (though this has exceptions), in being only capable of assimilating organic matter (except in the case of water and oxygen), and in having their cell-walls composed of nitrogenous matter, while in plants non-nitrogenous matter abounds. Higher animals are strongly differentiated from plants; the lower forms are often of doubtful position. Animals may be simple or complex, complexity depending on division of labour, and the consequent specialisation of function in organs which become differentiated from each other. The chief functions are Relation, Nutrition and Reproduction, the latter taking place during the stage when individual growth has ceased and while as yet repair exceeds waste.

CHAPTER II.

ORGANS AND CLASSIFICATION OF ANIMALS.

Method of Study.—The first branch of zoology necessary to be studied is the anatomy of the organism, and the best method of study is the examination of some of the commoner types of each class. As many of these are small, and optical assistance necessary, the student should provide himself with a good pocket lens. For dissection, the instruments required are, a scalpel, a fine-pointed pair of dissecting forceps, and several sharp-pointed needles fixed in wooden handles and with their extremities ground flat, so as to cut as well as tear. As many small animals can be most easily dissected under water it is convenient to have a shallow wooden tray lined with sheet lead for the purpose, while it often facilitates dissection to have a thin sheet of cork weighted with lead, so as to retain its position at the bottom of the fluid upon which the various parts may be pinned down. To preserve animal organs the best materials are, spirits of wine, or a weak (2 per cent.) solution of bichromate of potassium.

The study of the forms, nature and relations of organs to each other and to the organism in general,

FIG. 3.

Common orange Star-fish *(Astropecten aurantiacus).*

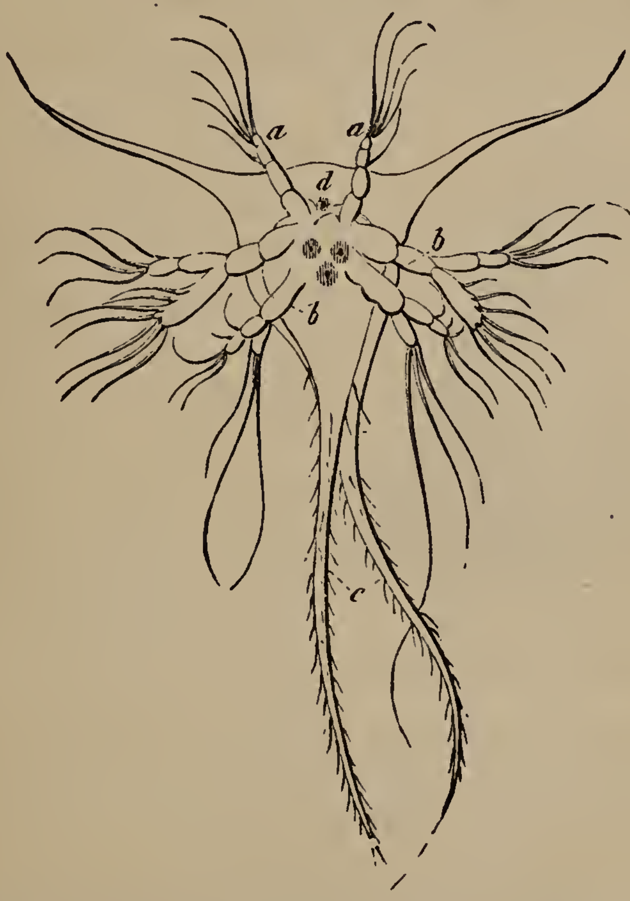
and the laws deduced therefrom is known as Morphology; the study of the uses of parts is called Physiology.

Morphology.—Groups of organs are generally symmetrically disposed in animals; either they are arranged in order around a central point in one plane, or else each individual consists of a succession of similar segments, as in a centipede. In the first case the symmetry is said to be radial as in the star-fish (fig. 3); in the second the segments are each made up of two symmetrical halves, and the symmetry is said to be bilateral.

In a perfectly symmetrical animal all the organs should be proportionally developed, but as the varying conditions of animal existence often require the more extensive performance of some duties than of others, we always find that some organs are larger, others smaller. In fact animals are so perfectly fitted to their surroundings that could we know all the conditions under which a given animal existed, we could form a good conception of its structure and *vice versâ.*

The Embryo.—To understand the true relations of structures in animals it is necessary to watch the growth of the organism from the earliest stages of its production in the egg until it attains its adult condition. The embryo is not a simple miniature of the full grown animal, but reaches its perfect state by undergoing a series of changes, which follow each other in a definite order. In this process, parts and organs start into being which were before unnoticeable, and some of these have only a transient existence fading off into nothingness. Thus the common acorn shell emerges from its egg as a little free-swimming larva (fig. 4), with eyes and feelers, but these totally vanish in the adult (fig. 5); such organs are known as *provisional* organs, and occasionally they leave traces behind when their functions have ceased, like the cord-like obliterated embryonic blood-vessels in mammalia. In some animals, during their development, organs spring into being for a shorter or longer period, but never perform any function and either vanish

FIG. 4.



Larva of common Acorn-shell (*Balanus porcatus*), showing antennæ (*a*), limbs (*b*), and eye (*d*).

or remain permanently in an undeveloped condition; such organs are called *rudimental*, and they are always such as in some kindred form discharge an important duty. Thus most cuttle-fishes have a groove in their body during their embryonic life, which closes in and forms a cavity wherein the internal shell is secreted; but the octopus or sea-spider, a closely allied form, has a similar groove which vanishes, leaving no trace behind. Instances of the kind might be multiplied, as there is scarcely an individual form in the higher sub-kingdoms which does not in its life history exhibit instances of provisional and rudimental organs.

Characters Essential and Adaptive.—In each animal we can divide the characters into two groups, essential and adaptive; the former of these are those whereby we can learn the relations of animals among themselves, and these are of primary importance in classification; the latter show the relations of the animal to its surroundings, but these in the adult often so overlie the essential characters as to obscure them. A study of the embryogeny of the animal will enable us to understand its relationship, for the adaptive characters are of later origin than the essential and may be traced as they are becoming superinduced. Thus among the parasitic mites of the genus Pentastoma, we could not know the true relations of the worm-like adults if we were not acquainted with the limb-bearing larva.

Fig. 5.

Adult form of *Balanus porcatus.*

Classification and Nomenclature.—The animal kingdom is a vast assemblage of individuals, and we require to arrange these in larger categories for purposes of study. Those individuals which are so far identical in structure as to lead us to believe that they are descended from common parents we speak of as belonging to the one species. *Species* is thus our unit in systematic zoology, but as two individuals are seldom absolutely identical in all respects specific distinctions must be more or less arbitrary. A group of allied species embodying the same structural ideas is called a *genus*. An assemblage of allied genera is a *family*; a group of related families make up an *order*; while related orders make up a *class*, and the several classes included in the animal kingdom are united in certain primary categories called *sub-kingdoms*. Systematic zoologists give a Latin name to each of these, and for convenience each species is designated by a Latin word to which is prefixed the name of the genus. The specific name is generally an adjective, the generic is a substantive, and should be written with a capital letter. Thus the dog is called by zoologists *Canis familiaris*, Canis being the generic, familiaris the specific name. *Canis aureus* is the jackal, *Canis lupus* the wolf. That species in a genus which most strikingly embodies the generic characters is the type of the genus. We also speak of the type of a family, of an order, or of a class, the type being that species which displays most clearly the characters of the group; and for convenience we attribute certain characters to ideal types to illustrate truths in classification.

The type genus usually gives its name to the family, thus the dog-family is called Canidæ.

Homology.—In comparing animals, the most important resemblances are those which depend on common relationship to the types of the class to which they belong. These likenesses are called resemblances of morphological type. Thus if we compare a dog and a crow, we find in both a skeleton, a brain, a skull, four limbs, a heart &c., and we refer them both to the vertebrate type, inasmuch as they both embody the ideas of structure characteristic of vertebrate animals. Each part in one is said to be homologous with the corresponding part in the other, the wing with the fore leg, &c. Homology is thus identity of structure irrespective of function, and parts are homologous which represent the same parts in the ideal type of the class. Such resemblances are the bases of classification.

Analogy.—Likenesses of parts may also depend on similarity of function; thus the wings of insects and the wings of birds are used for the same purpose, and have certain resemblances. These similarities are called resemblances of analogy, and they tell us nothing as to the nature of the organs compared.

Fig. 6.

Leaf insect (*Phyllium siccifolium*).

Mimicry.—Animals of definite geographical areas often resemble each other in some respects; thus they may be mostly similar in colour, mostly white, or spotted, or striped, or brightly coloured. Sometimes animals mimic in shape or colour the leaves and twigs on which they live (fig. 6), or the prevalent colour of the herbage. Thus the Kakapo or ground parrot of New Zealand, which can hardly fly, is in plumage like the mottled green vegetation among which it lives. The ptarmigan and other birds become white in winter, so as to become inconspicuous among the snow. Sometimes an insect mimics in appearance another of different nature living in the same district. In such cases the insect imitated is one which, from its disagreeable secretions or sting, is not a favourite prey of insect-eaters. Hence the mimicry protects the imitator, who is usually rarer than the insect imitated.

Organs which are homologous consist of homologous parts ; and as this is not the case in organs resembling each other only in function, we must be careful to discriminate morphological from physiological likeness.

In animals which consist of successive segments in a chain, like centipedes or lobsters, each segment is composed of parts similar to those of its neighbouring joints. Such parts are said to be serial homologues, as for example the fore and hinder limbs of quadrupeds.

CHAPTER III.

CLASSIFICATION AND DISTRIBUTION OF ANIMALS.

Sub-Kingdoms.—The animal kingdom includes eight sub-kingdoms. In these we observe a certain progressive increase in complexity, from one end of the series to the other ; but they do not make a linear series, as the highest organism of each is in no degree related to the lowest organism of the next sub-kingdom, being usually much more advanced and specialised, so that in point of complexity the sub-kingdoms overlap each other.

The first sub-kingdom, Protozoa, includes those animals which have neither body-cavity nor nervous system, and are single celled.

Sub-kingdom 2. Polystomata, includes sponges, which have an internal cavity with a three layered wall, one outlet, and usually many inlets, but no differentiated organs, though consisting of many cells.

Sub-kingdom 3. Cœlenterata, includes jelly-fishes and sea anemones, having a stomach cavity and a body cavity as an outgrowth therefrom, and a radiate symmetry.

Sub-kingdom 4. Echinodermata, includes starfishes and sea-urchins, with a body cavity separate from the stomach, a nervous system, and a system of water-tubes which are agents in locomotion.

Sub-kingdom 5. Vermes, includes worms which are bilaterally symmetrical, and composed of successive similar segments, with no jointed limbs, and with a water-vascular system which has no locomotory function.

Sub-kingdom 6. Mollusca, includes oysters, snails, &c., possessing soft bodies enveloped in a leathery mantle, no jointed limbs, a circulating system, often an external shell and often an unsymmetrical nervous system.

Sub-kingdom 7. Arthropoda, includes crabs, lobsters, spiders, and insects, which have bodies made up of successive joints, with a symmetrical nervous system, an external skeleton and jointed limbs.

Sub-kingdom 8. Vertebrata, including fishes, reptiles, birds and quadrupeds, which have an internal skeleton, a brain and vertebral column. This one sub-kingdom includes the most complex of animals whose structure requires more minute examination than does that of the other sub-kingdoms. We will in the present volume consider the seven invertebrate sub-kingdoms.

In comparing these sub-kingdoms, we speak of forms as being high or low in organisation according to the degree in which special parts are appropriated for the discharge of special functions. We also notice that no organ appears for the first time in animals in a state of complexity, but on the contrary, there is always in lower forms a prophetic foreshadowing of it in the modification of some part already existing.

Distribution.—Every species of animal is limited to a definite geographical area. Thus the earth's surface may be divided into regions, each characterised by special inhabitants, and the collected animals of any region we speak of as its fauna. As a rule, life increases in amount in any country with increasing, and diminishes with diminishing temperature. Thus the fauna of a tropical exceeds that of a temperate region. The number of animals is also larger when the difference between the winter and summer temperature is small, than in a country with the same mean temperature but with a greater range between maximum and minimum. Moisture is also favourable to animal life, and the fauna of a moist exceeds that of a dry region, other things being equal.

Many animals live in places from which light is excluded, as in caves; these have rudimental eyes, and are white or colourless. Many large caves, like those of Kentucky, Adelsberg &c., have thus peculiar blind faunæ.

Sometimes the presence of one animal prevents the diffusion of others; thus in Africa the tzetze fly renders whole tracts uninhabitable by oxen and deer, which are destroyed by its poisonous bites.

The fauna of a limited area of a continent usually exceeds that of an island of equal size in its number of specific forms; and the fauna of an island lying near a continent resembles that of its neighbouring continent. Oceanic islands or those isolated by very deep straits have often remarkable faunæ of their own, *e.g.*, the Galapagos and New Zealand.

Tropical species are, as a rule, more limited in range than are those of temperate climates, and simpler animals are usually more widely distributed than are the more complex.

Fresh-water inhabitants are the fewest specifically, and as a rule are simpler in organisation than allied forms inhabiting other media. The fourth sub-kingdom has no fresh-water representatives; the second has only two, and the third only five species living in this medium; while the others are not very numerously represented in fresh-water.

The sea is the home of nine-tenths of the invertebrates (if we exclude insects), and there are also definite ranges of extension to be noticed in the cases of marine species. The conditions limiting specific life in the sea are depth, currents, and temperature.

Terrestrial animals are the most specialised, and have organs in a more concentrated condition than in their aquatic allies.

Parasitism.—Some animals pass their lives within or on the bodies of others, and this condition induces striking alterations in structure. In some cases the intruder collects its own food independently of his host, being thus only indebted to him for house room ; of this nature are the sponges which live rooted on crabs, or the barnacles on the skin of the whale. The second series of intruders are fellow commoners with their hosts, feeding on the food which their entertainer collects ; while in a third class the parasite is a pensioner on the body of his host, feeding on his substance. Such forms are true parasites.

In all these conditions there is a diminished necessity for locomotion and for food-capture on the part of the parasite ; so the organs of motion, of sense, and of nutrition retrograde, but as the parasitic condition involves difficulties in the continuance of the species, the organs of multiplication are enormously increased in size and complexity.

Extension in Time.—Species of animals have limited ranges in time as well as in space, for they are dependent on the constancy of physical conditions for their specific longevity, and such alterations in these as are constantly occurring will tend to extinguish species ; hence the history of life in the past is a continual record of the dying out of types of life.

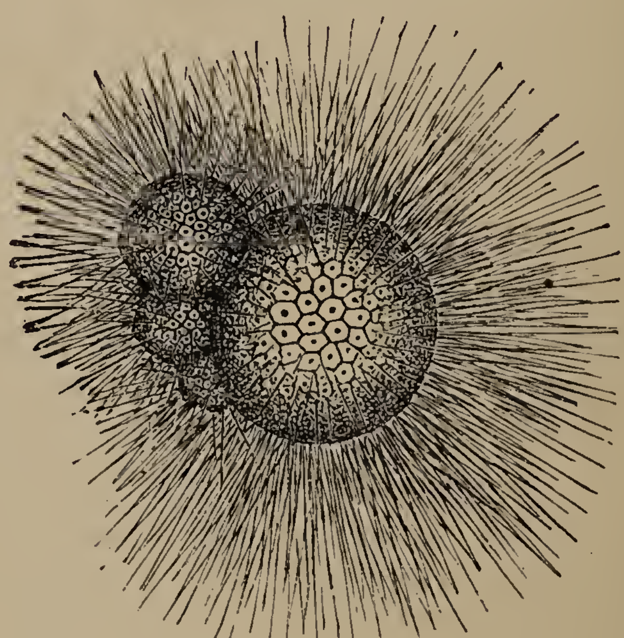
CHAPTER IV.

SUB-KINGDOM I: PROTOZOA.

General Characters.—The constituent animals of this sub-kingdom are animals of extreme simplicity, consisting for the most part of undifferentiated protoplasm. None of them possess a nervous system, sense organs, nor a body cavity, nor do we find differentiated organs present in any of them.

Among these there are five chief types forming five classes.

FIG. 7.



One of the minute Foraminifera, *Globigerina bulloides*, magnified seventy diameters.

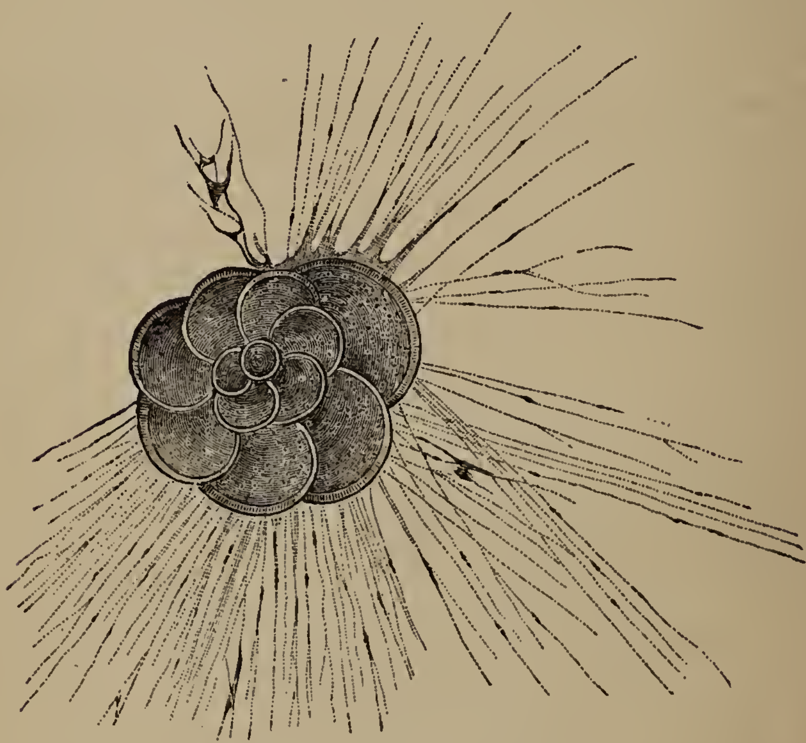
Certain forms, called Monera, are even simpler than the Rhizopods, as they not only want the power of house-building but have no nuclei, and are thus the simplest conceivable living beings, mere specks of living jelly (fig. 9). Of these naked forms, some authors make a separate class under the name Monera.

Class 1. Rhizopoda.—In the fine white sand on the sea-shore or in the mud of the sea-bottom there are to be found minute calcareous shells of varying forms, ranging from $\frac{1}{300}$th to $\frac{1}{10}$th of an inch in diameter. Each shell consists of many separate chambers, arranged either one after another in a straight line or in a single or double spiral, or even grouped in more complex fashions. Each chamber is separated from its neighbours by a partition which is pierced with one or many holes whereby the several chambers communicate with each other. The shell-substance is either white and porcelain-like, or glass-like and more brittle, and pierced not only in the partitions but over its whole surface by numerous holes. On account of these perforations these little shells are called Foraminifera (hole bearing).

The animals which build these wonderful houses are exceedingly simple in their structure. The interior of each chamber in a fresh state is filled with protoplasm which is jelly-like, highly contractile on being irritated, and not only extends through the holes in the shelly wall but coats the outside of the shell with a glairy external living layer. This layer has no definite uniformity of outline, but is constantly changing its shape by sending into the surrounding water radiating protoplasmic processes which are inconstant, rapidly retracted, disappearing by being taken into the homogeneous matter of the animal's body, and coalescing when they touch each other. To these the name *pseudopodia* (false feet) has been given.

These little creatures live on any minute organic particles with which they come in contact, and their mode of feeding is simple; when the ray-like pseudopodia touch a particle of which they seem to approve as a prospective meal they converge around it, and

FIG. 8.



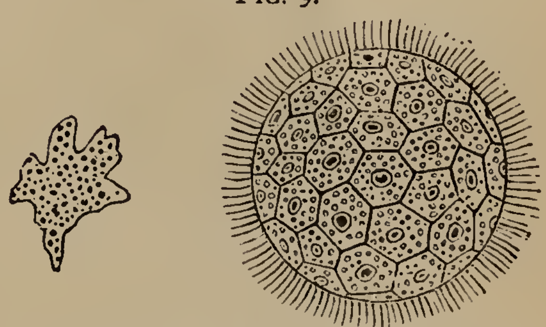
Rotalia Veneta, a Rhizopod, showing the pseudopodia.

touching each other coalesce, and draw the particle within the body proper, in which it is digested. As these creatures are homogeneous or nearly so, any one spot is as suitable for the protrusion of pseudopodia or for the taking in of food as another, but usually the processes are most numerous opposite the holes in the shell.

As the protoplasm includes its food in the manner described, foreign particles and fine granules become enclosed in it derived from the undigested parts of the food. Sometimes drops of water or of thin fluid may be seen in the protoplasm like little bubbles; these are called *vacuoles* (fig. 14), and they with the granules circulate actively in the body mass; obscure condensed points or nuclei also exist, and the name of the class is derived from the root-like spreading of the pseudopodia.

Mode of Growth of Rhizopoda.—Those Rhizopods that separate lime from the sea-water to form shells, begin the process while they are young single masses, and they increase by budding, each bud forming on the newest end of the last bud; consequently the perfect animal consists of a rod-like or spiral set of chambers, each chamber being a new, undetached bud. Some buds become quite separate and grow into new individuals. In a few cases each bud becomes detached, so that the animals always remain of one chamber.

Fig. 9.

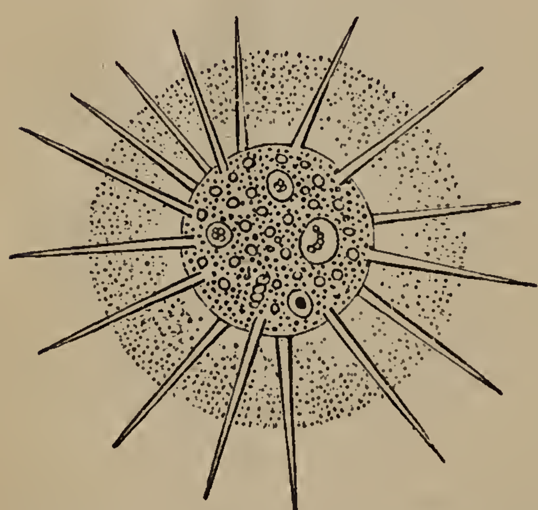


Two forms of Protozoa. *Protamœba primitiva*, the simplest living animal; *Magosphæra planula*, a compound form.

Shell-forming Rhizopods are occasionally aggregated in great masses and sometimes at great depths in the ocean. Such seems to have been their habit in past times, and many of the chalky limestones consist of the accumulated shells of Foraminifera.

Class 2. Protoplasta.—In the slowly running waters of ditches, or in bog pools, are found curious creatures in many respects reminding us of the naked Rhizopods. These amœbæ as they are called, are little masses of protoplasm, moving and taking food by means of pseudopodia. On close inspection many particulars will be noticed, in which they differ from those simple creatures which we have already examined. Thus their pseudopodia are blunt, and do not freely coalesce, on touching each other; the granules and vacuoles are not uniformly distributed through the protoplasm, but are for the most part in the central region, while the outer protoplasm is firmer. We also notice a denser central spot in the body, to which the name *nucleus* is given, as can be seen in each component mass of Magosphæra (fig. 9); and one or more little clear spaces may be seen occasionally to contract and expand alternately. Thus in the group of organisms of which *amœba* is the type, protoplasm has become partly differentiated, that is, some parts have assumed characters which the simple protoplasm did not possess. On account of this first trace of the development of tissue we call this group of

Fig. 10.

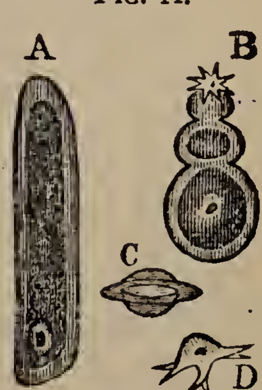


Heliophrys variabilis. One of the Sun animalcules showing the pseudopodia, nuclei, vacuoles, &c.

animals *Protoplasta* (first tissue). The amount of this differentiation is in some scarcely recognisable, while in others, the sun animalcules or *Heliozoa* (fig. 10), there are many nuclei, and each of the fine ray-like pseudopodia exhibits distinctly an inner axis of the granule-holding protoplasm and an outer layer of firmer material. These animals multiply by division, and in modes of feeding, &c., they resemble the Rhizopods, with which they are often united.

Class 3. Gregarinæ.—A group of curious parasites, the *Gregarinæ*, manifest a similar process of differentiation taking place in their life-history. These minute creatures are found in the digestive canals of beetles, earthworms, &c., and in their mature states they appear as elongated bodies with a firm outer wall which never becomes protruded, and consequently does not allow of the formation of pseudopodia (fig. 1, A, B). This outer stratum may itself consist of two layers; while internally the protoplasm contains a solid nucleus. At a certain stage in its existence the adult Gregarine becomes almost globular and quiescent, loses its nucleus, and its internal material becomes aggregated into many boat-shaped bodies, contained within the firm outer layer through which they eventually burst; each of these boat-like bodies (fig. 11 C) consists of a rigid outer case and an inner

FIG. 11.



A. Gregarine from the Earthworm. *Monocystis lumbrici.*
B. Gregarine from the dragon-fly. *Pixinia rubecula.*
C. Boat-shaped body or Pseudo-navicella.
D. Amœbiform body set free from Pseudo-navicella.

particle of protoplasm. The former soon gives way, and the inner portion, freed from external restraints, moves actively by pseudopodia like a Rhizopod (fig. 11, D). On reaching a suitable nest this amœboid particle undergoes further development, and becomes a Gregarine like its parent. In size these parasites range from the $\frac{1}{50}$th to $\frac{2}{3}$rds of an inch.

Class 4. Radiolaria.—On examining the material brought up from ocean bottoms, there are frequently found small and beautifully sculptured shells, differing from those of the Foraminifera in that they consist of silica, not of lime, and hence they are comparatively indestructible by maceration in acids, by which process they can be isolated from the mud wherein they are found. In pattern these shells frequently consist of symmetrical, radiating rods, united by a variously patterned interweaving of threads of silica, the whole making a network often resembling flower-baskets, disks, and perforated spheres, hour-glasses, or helmets.

FIG. 12.

Flinty Shell of a Radiolarian *Eucyrtidium lagena.*

The animals which form these exquisitely ornate little shells are found to be comparatively simple, and in many respects allied to the Rhizopods, as they send out fine thread-like pseudopodia, from the surface layer. The deeper protoplasm is enclosed in a central membranous capsule, perforated with holes, and it contains fat, cellular masses, pigment and often a central vesicle or sac with striped walls; curious yellow cells are found scattered through the body in almost all species.

In size these Radiolarians are from $\frac{1}{2}$ to $\frac{1}{600}$th of an inch in diameter, the larger forms, however, are not single individuals but clusters united into compact colonies, each component individual having its own central capsule. Most of these are found floating on or in the waters of the sea. Some oceanic forms have no skeleton, and are described under the name sea-glue (*Thalassicolla*).

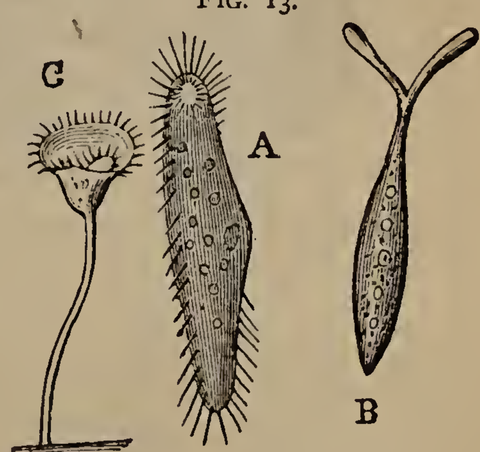
Some allied forms, destitute of central capsule and of yellow cells, are found in fresh-water bog pools in this country.

CHAPTER V.

SUB-KINGDOM I: PROTOZOA—*continued.*

Class 5. Infusoria.—If we place under the microscope, water in which animal or vegetable matter has been infused for six or seven days, especially in warm weather, we see that the fluid contains minute, actively moving creatures ranging in size from $\frac{1}{25}$th to the $\frac{1}{2400}$th of an inch in length. They are mostly oblong in shape and their rapid locomotion is due to the action of fine vibratile cilia which clothe, either the whole

Fig. 13.



Three Ciliated Infusoria.
A. *Oxytricha gibba.* B. *Trachelocerca biceps.* C. *Vorticella citrina.*

surface, or else special areas of it; sometimes a few of these processes are rigid and act like little feet, or else they are all equal and fine, invisible during their active exercise owing to their rapid rate of motion.

The outer layer of their body is a firm cuticle which covers a differentiated protoplasmic lamina con-

FIG. 14.

Paramæcium aurelia, an infusorian, showing the contractile vesicles (*v*), cilia and vacuoles (*a*).

taining one or more clear spaces or *contractile vesicles*, which when watched can be seen to expand and contract regularly, pulsating like a heart. Within this layer is a more fluid mobile protoplasm containing granules, vacuoles and a pair of singular solid bodies called respectively nucleus and nucleolus.

Near one end of the body there is usually a funnel-shaped mouth opening into the inner protoplasm, where digestion takes place, as in Rhizopods; the undigested particles are ejected at a spot where the outer wall seems deficient, and which sometimes is a distinct opening.

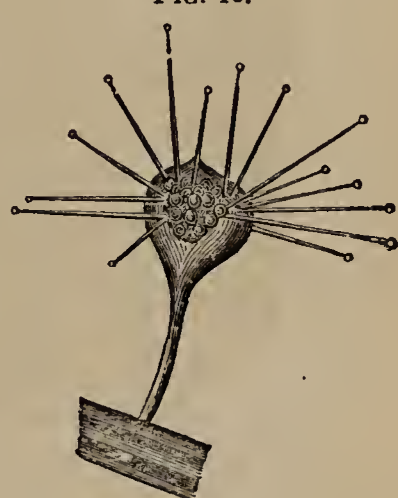
These animals multiply either by fission like most of the other Protozoa, or else the nucleus breaks up into egg-like masses which seem to develop into new infusoria. This condition is preceded by the formation of a mucous mass around the animalcule, which becomes quiescent, losing its cilia.

The Vorticella, or bell animalcule (Fig. 13, c) is a common form fixed by a slender footstalk, which on

FIG. 15.

Noctiluca miliaris, a marine luminous animacule, showing its flagellum.

FIG. 16.



Acineta mystacina.

irritation instantly contracts into a spring-like spiral and the ciliary crown around the mouth of the bell becomes introverted. Another common form, *Ophrydium*, has an outer gelatinous envelope, and as division proceeds, this keeps the broods together so that they sometimes form masses of more than an inch in diameter, which are often found floating on standing water. The commonest forms are the slipper animalcule (fig. 14), the boat-like animalcule or *Euplotes* (fig. 1), and the hay infusion animal or *Colpoda*, but almost every infusion has its own form of animal.

Several groups of microscopic animals are allied to the Infusoria. Some of these are called *monads* and are mouthless nucleated bodies with one long cilium. Another of these is Noctiluca (fig. 15), a globular creature about $\frac{1}{50}$th of an inch long, with a short obtuse vibrating *flagellum* or filament and a mouth, but whose interior consists of netted protoplasmic threads whose meshes are filled with water. These organisms are among the commonest of those to which the sea owes its phosphorescence.

Other minute forms, called Acinetæ (fig. 16), are small, stalked masses whose surface is studded with radiating, retractile tubular suckers, through which they suck the juices of their prey.

CHAPTER VI.

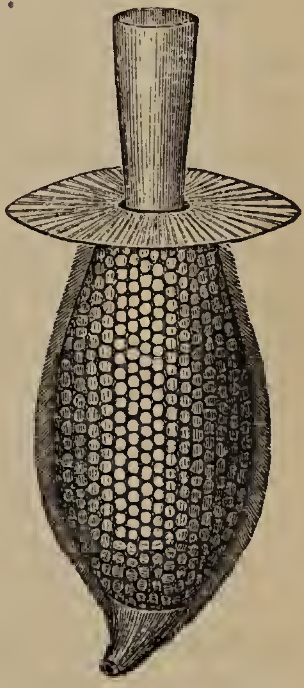
SUB-KINGDOM II: SPONGES (POLYSTOMATA).

Metazoa.—All animals above the Protozoa possess an internal body-cavity, the wall around which is made up of three primary layers, often with difficulty discriminable in the lowest forms; and there is either one terminal mouth into the cavity, or, as in the case of the sponges, many lateral pores communicate therewith.

Characters of Sponges.—The common toilet sponge is a representative of a group of animals whose affinities are not easily understood. On examination with a magnifying glass it will be found to consist of irregularly branching and re-uniting threads of a highly elastic material, so arranged that the interspaces between the finer branches appear as pores or canals, which, from the nature of their walls, freely communicate with each other.

On examining the surface of a sponge, some large holes will be seen, which, on being cut into, are found to be the extremities of wide spaces or tubes; these divide within the sponge-mass into smaller canals, which again divide and subdivide until finally they end in the fine canals whose terminations are the minute surface pores between the superficial fibres of the mass. The walls of these spaces are themselves full of small pores in the interstices of the fibres which form the substance. This horny mass is really the sponge skeleton, having the same relation to the sponge animal that the spicules of Radiolarians bear to the soft parts of those creatures.

Fig. 17.



A calcareous sponge.

We can most easily understand the nature of a sponge animal by examining such simple forms of the group as may be found encrusting sea-weeds or stones on our own shores. These are nearly cylindrical, rooted by a flat protoplasmic expansion below (fig. 17), and have a single wide opening above, which is named the *osculum*. Its walls are pierced by numerous fine apertures or *pores*, which open directly into the central cavity. The wall consists of a cluster of Monad-like cells, provided with a collar, each sending out a pseudopod. In the wall and around each of the lateral pores are needle-like spicules of carbonate of lime usually united in threes, and arranged in a radiated manner. Sometimes they are in pairs or in twos. Others are like anchors, with two flukes.

As in most sponges the wall of the body-cavity beloweach mouth is thick, not simple and membranous, the pores elongate into canals. Most sponges also grow in tufts or clusters arranged so close together that the outer pores of the neighbouring, and closely united animals communicate with each other ; thus a complex canal system grows up, according to the degree of thickening of the wall and coalescence of separate elements of the clusters, as well as by the superaddition of interspaces, which are often branched, between the separate individuals or elements.

In a living sponge, currents of fluid set in through the minute pores on the surface, setting out in large streams through the oscula ; thus there are many mouths and few outlets. These currents are kept up by the waving of the flagella which bedeck the protoplasm masses that line the canals and cover the skeleton, and as these currents traverse the canals the small organic particles which they carry in are taken up by the cells of the wall in the same manner as food particles are swallowed by Rhizopods.

Spicules.—The skeleton of most sponges consists not only of the horny material with which we are familiar in the toilet sponge, but of spicules of silica of various shapes embedded in the horny mass, resembling pins, needles, clubs, crosses, anchors, hooks, wheels, &c. In others, siliceous spicules alone make up the skeleton, which has no horny matter. There is a calcareous skeleton in another group.

Reproduction and Classification. — Sponges multiply by division, either natural or artificial. That is, if we cut up a living sponge into many small pieces, each can grow into a perfect sponge. Other modes of growth or reproduction are by continuous budding, by the formation of free buds, usually arising in autumn and growing in the ensuing spring, or else by the formation of eggs which have been found in summer in many forms, and which develop in the following year Sponges are classified according to the material of the skeleton and the shapes of the spicules. Thus there are calcareous, horny, and siliceous sponges. The last class is the largest and includes some remarkable forms, such as the boring sponge (*Cliona celata*), which pierces holes in old oyster shells on our sea-shore, and is known by its pin-shaped spicules. The remarkable Neptune's cup (*Raphiophora*) is closely allied, though very dissimilar in shape and size. *Hyalonema*, the glass rope, from Japan and Portugal, has long twisted siliceous spicules. *Euplectella*, the exquisite Venus's flower-basket, from the Philippines, is now well known as an ornament, and exhibits a most wonderful interweaving of siliceous spicules. *Spongilla*, the common green fresh-water sponge of lakes and rivers, is a familiar form, and each autumn it will be found to display the formation of winter gemmules or free buds. *Halichondria* (Chalinula) is the common sponge found on our sea shores, and *Sycandra* is the compressed white calcareous sponge found pendulous from rocks, or adhering to sea-weed near low-water mark.

CHAPTER VII.

SUB-KINGDOM III: CŒLENTERATA. CLASS I. HYDROZOA, JELLY-FISHES.

General Characters of Hydra.—The common *Hydra* (figs. 2 and 18), an inhabitant of our stagnant pools, is the type of the third sub-kingdom of animals. This voracious creature rarely exceeds half an inch in length, and possesses a cydrical body having the mouth at one end and a sucking disk for voluntary attachment at the other. Around the mouth are six, seven, or even ten slender contractile arms, capable of rapid motion, and about as long as the body, or even longer; these can be seen actively engaged in seizing prey and dragging it into the central mouth (fig. 18 T). The body is composed of two membranes, an outer and an inner; the former, which is called *ectoderm* (outer skin), making up the whole outer surface, the latter (called *endoderm* or inner skin) lining the interior

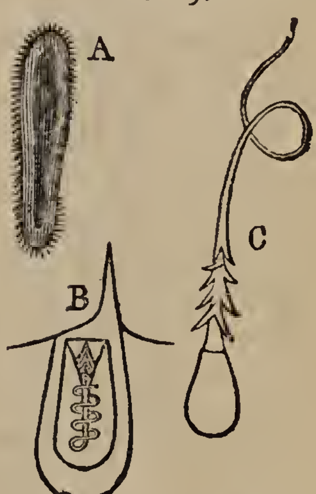
FIG. 18.

Hydra aurantiaca, the orange hydra, showing its tentacles and reproductive organs.

of the body, which consists of a simple stomach cavity from which the effete matters are ejected by the mouth.

On watching the process of feeding we notice that the arms exercise a power over living prey far greater than we could anticipate from their size; and on close inspection these *tentacles* (as the arms are called) are seen to be covered with minute oval sacs, whose outer thin walls (fig. 19 B), are easily burst by pressure, and when this occurs a long whiplash-like filament (C) which lay coiled within the cell, is suddenly projected, thus rendering the tentacle a formidable organ for seizing prey, their action being either mechanical, or by virtue, possibly, of some poisonous fluid.

FIG. 19.



A, Planula or earliest stage of a hydroid on its emission from the egg. B, Thread-cell undisturbed. C, the same with the filament protruded.

The cells of the outer layer in *Hydra* have, projecting inwards or towards the endoderm, slender thread-like contractile processes, acting like muscular fibres. The ectodermal cells resemble nerve cells, and hence to this stratum the name *neuro-muscular cell-layer* is given.

Reproduction. — Hydras in early summer send off from near the base of the body small buds (fig. 2), which grow rapidly, each developing a mouth at its free end, together with a crown of tentacles, then, being detached, it assumes a separate existence. Sometimes a second crop of buds arises from the first bud before it has detached itself from its parent.

Later on in the season, eggs form within the Hydra, beginning as modified cells of the inner layer. These

FIG. 20.

Sertularia abietina, one of the sea-firs; *a* natural size, *b* magnified. The figure shows the stem, or cœnosarc of the colony, with its polypites.

burst through the surface (fig. 18, *o*), become free, and in spring they shed their outer layer and proceed to develop into new Hydræ, which in course of time give rise to buds.

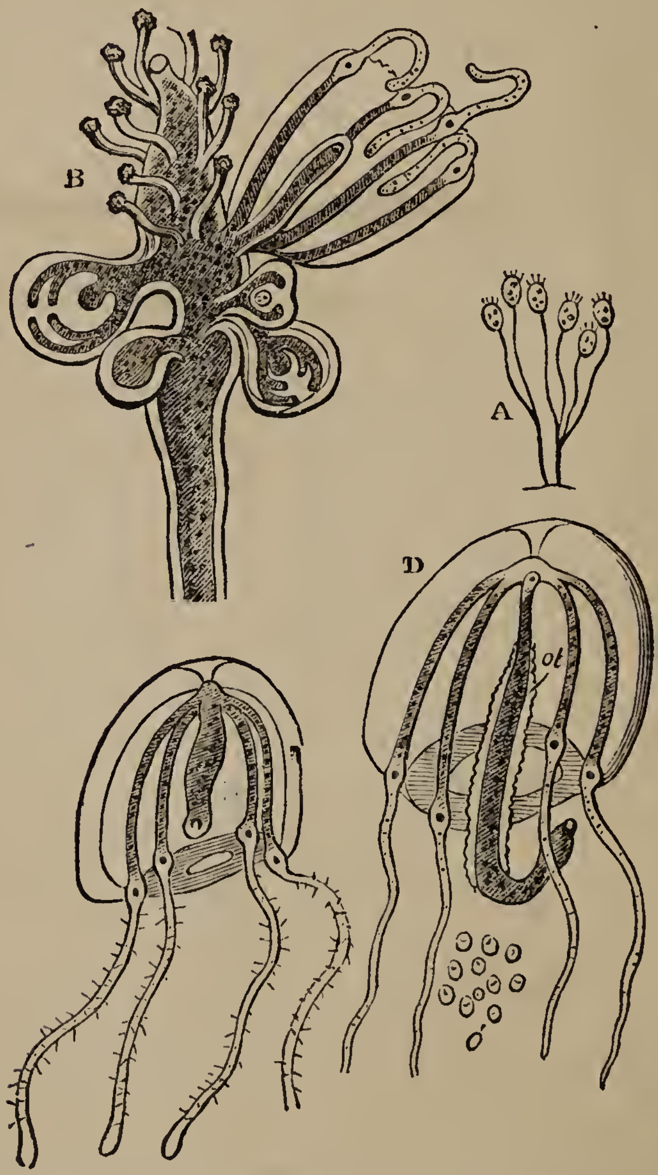
Sub-Class 1: Hydroida.—All the lower cœlenterate animals are built on the pattern of the hydra, they only differ in the details of their organisation and arrangement. In many of the marine forms, the hydra-like animals are grouped in clusters or colonies on a branched common axis or stalk (fig. 20). In each of these colonies every hydra-like organism is called a *polypite*, and the common stalk of the colony is called the *cœnosarc*.

These colonies we find on the sea-shore as branching tree-like growths on sea-weeds, often exceeding six inches in length, and some of them are known as 'sea-firs.' Each group begins its existence as a single polypite, rooted by that extremity of its body which is opposite to the mouth. From this root a stalk of cœnosarc grows upwards, and on this stalk new polypites form, each like a hydra in structure. New polypites arise as outgrowths from, and are structurally continuous with the common stem of the colony; and so the stomach of each is continuous with the tubular centre of the stalk. On this account there is a community of nutrition in the colony, a few actively-feeding polypites being able to make up for the laziness of others, which participate in the nourishment taken in by their more active neighbours.

Medusoids.—In these colonies some polypites are set apart for the production of eggs for the multiplication of individuals (fig. 21, C, D). Such polypites are much altered in form, and they frequently become detached from the stem and float about freely often as little jellyfishes about the size of a pea; they are called *medusoids*. With a fine muslin surface-net in any of our seas, many forms of these little creatures may be captured, especially in summer or autumn;

each appears somewhat umbrella-shaped, and the margin of its disk or swimming bell is adorned with

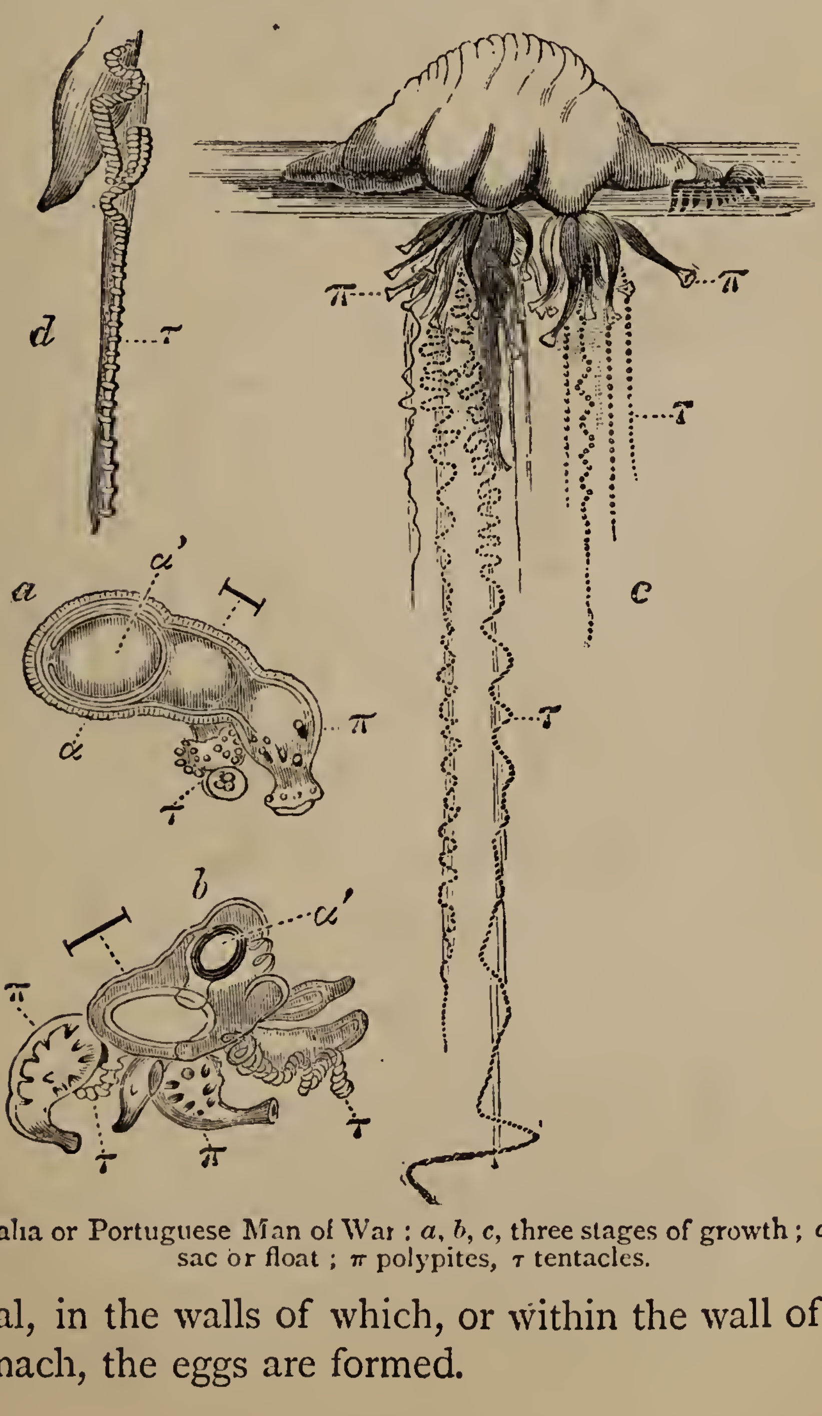
FIG. 21.



Different stages of Medusoids: A, rooted hydroid colony, natural size; B, polypite magnified, showing tentacles and swimming bells; C, D reproductive swimming bells, detached and free-swimming.

little, naked, coloured specks supposed to be eyes, and also with marginal tentacles. A central mouth exists on the under side of the swimming bell, opening into a stomach, from which four tubes radiate to the margin of the bell, where they are united by a circular

Fig. 22.



Physalia or Portuguese Man of War: *a*, *b*, *c*, three stages of growth; *α′*, air-sac or float; *π* polypites, *τ* tentacles.

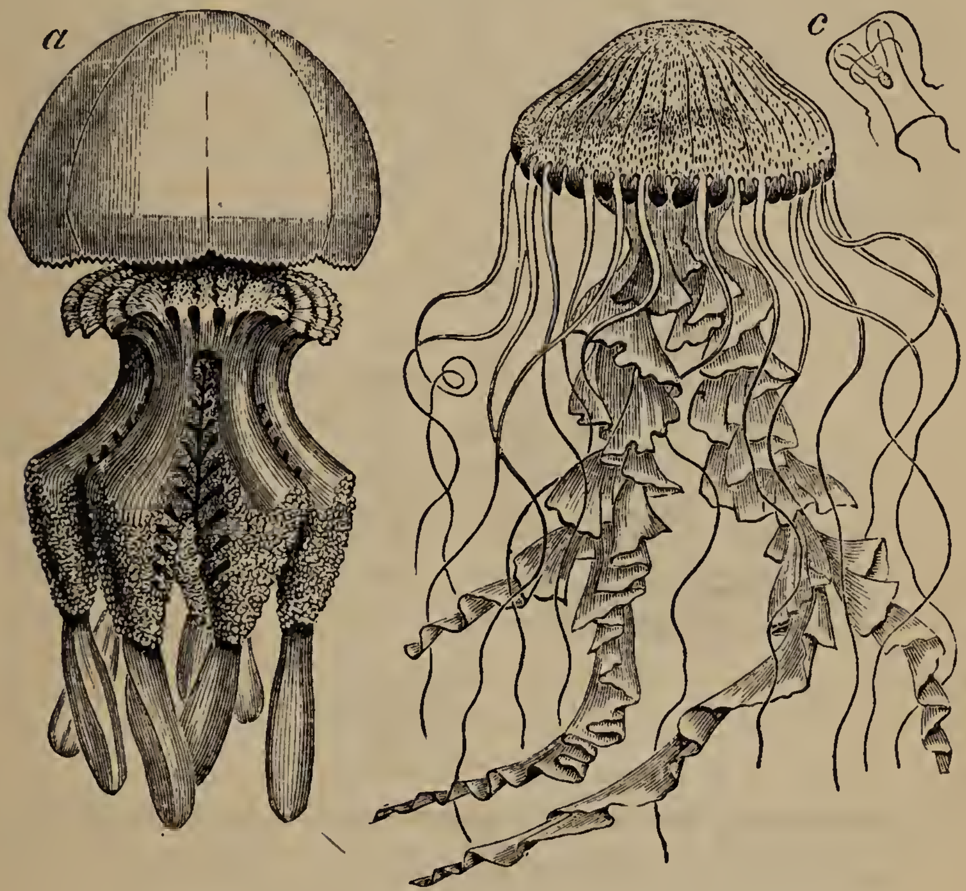
canal, in the walls of which, or within the wall of the stomach, the eggs are formed.

Unlike as this jellyfish may appear to be to Hydra, it is in reality a polypite modified by a widening and thickening of the body wall at the base of the tentacles, and an elongation of the mouth into a central stalk. These free-swimming jellyfishes are thus not distinct animals, but only detached parts of hydroid colonies, and the eggs produced by them first give origin to small ciliated, infusorium-like bodies (p. 25), called planulæ (fig. 19, A) which after a short period of freedom settle on stones or shells at the sea-bottom, and develop into primary polypites and the common stem of a new colony, from which some buds becoming specialised and detached form in turn medusoids. There is thus an alternation of generations, the progeny of the egg resembling, not the immediate egg-producer, but the form which preceded this.

Divisions of Hydroida.—Of fixed Hydroids there are three orders: 1. simple forms, such as Hydra; 2. compound colonies whose stalks, polypites, and medusoids are naked (fig. 21); 3. compound colonies whose stalks and polypites are covered with a horny casing as in the true sea-firs (*Sertularia*, fig. 20).

Sub-Class 2: Siphonophora.—Floating on the sea there are frequently found colonies of hydroid polypites, not unlike those of the sea-firs in structure, but whose common stem instead of being rooted, swims by means of enlarged and altered polypites, whose stomachs are undeveloped, and whose bodies are dilated into swimming bells. From these, the cœnosarc extends, supporting both the nutritive and the reproductive polypites. Some possess in addition a sac filled with air which acts as a float and aids the swimming bell in locomotion. This is seen in the Portuguese Man of War (fig. 22), whose purple crested air sac and long tentacles are well known to sailors, and which, by their large thread-cells, inflict dangerous stings on those who incautiously touch them. These

Fig. 23.

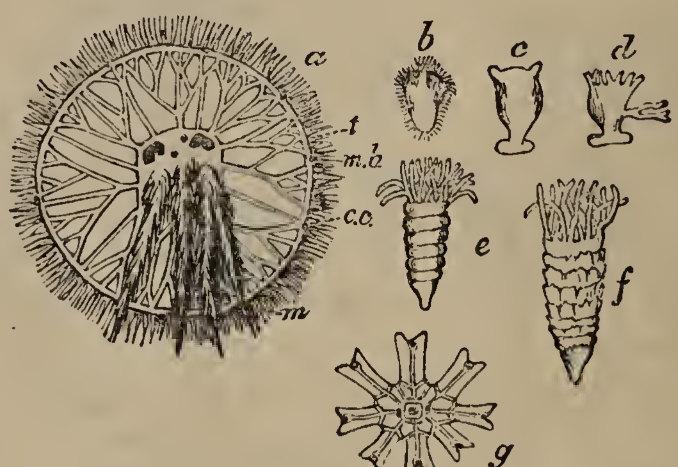


Disk-bearing Jelly-fishes; *a*, Rhizostoma; *b*, Chrysaora.

swimming and floating colonial Hydroids are called Siphon-bearers (*Siphonophora*).

Sub-Class 3: Discophora.—The large jellyfishes whose translucent bodies are so often thrown on the shore by the receding tides, are the representatives of a sub-class characterised by possessing single polypites depending from the centre of a large disk or umbrella varying from an inch to three feet in diameter. The mouth of the polypite is surrounded by lobate tentacles (fig. 24), and from the stomach there pass eight or more branching radial canals which are united peripherally by a circular canal. The eggs are produced in pouches of the stomach-cavity, and each of these on ripening emits a ciliated germ like an infusorium (fig. 24 *b*), which after a brief locomotory existence settles down on some solid body at the sea bottom (*c*), and develops a hydra-like animal with

FIG. 24.



Medusa aurita in different stages of life ; *a* perfect adult form reduced $\frac{1}{15}$; *b*, *c*, *d* hydra-like stage; *e*, *f* strobila stages ; *g* one of the disks separated from *f*, and growing into adult form.

branching canals which, elongating, forms a little rooted colony (*d*). Each of these hydra-like forms becomes marked with transverse furrows (*e*) which, deepening, dip into the interior of the body dividing it into a vertical 'pile of saucers,' of which each discoidal segment becomes free as a new medusa. This is a good example of alternate generations.

In the common *Medusa aurita*, whose disk can easily be recognised by the four, ring-like, violet ovaries, there are marginal tentacles and also little pigment spots and clear vesicles (eyes and ears) symmetrically disposed around the disk, each covered by a little lobe of the umbrella margin. There is no trace of a marginal membrane or veil, such as exists around the mouth of the bell of hydroid medusæ.

Thread Cells and Nervous System.—The stinging power of these 'sea nettles' is due to their armature of thread cells.

When a hydroid is cut in pieces, each piece becomes a perfect animal if a portion of the margin is preserved, but if not, reproduction is very uncertain.

In these medusoids we meet for the first time with an area of sensitive tissue acting like a nervous system, and connected with the margin of the disk. If this be preserved motion continues to take place, whereas if the margin be cut away motion ceases.

Many medusæ are phosphorescent, emitting light from the whole surface, especially from the margin of the disk.

Ctenophora.—In one interesting little group, a fourth sub-class, called *Ctenophora*, there are eight radial rows of comb-like plates armed with cilia, which act as rowing organs. In these there is a certain amount of bilateral symmetry.

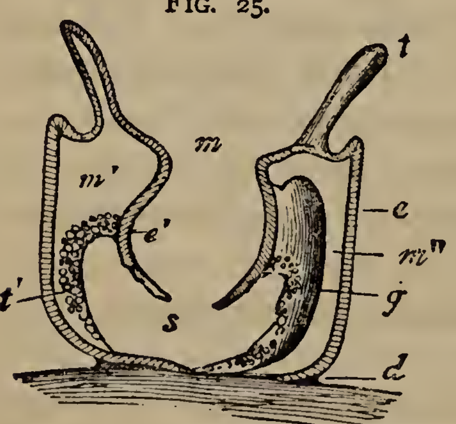
Summary.—The Hydræ and jellyfishes which constitute the class Hydrozoa possess a central stomach cavity into which a single aperture of entrance leads. They are also armed with thread-cells and possess a body wall of two layers.

CHAPTER VIII.

ACTINOZOA. SUB-CLASS I. ZOANTHARIA: SEA ANEMONES.

Structure of a Sea Anemone.—In many of the rock-pools around our shores there are to be found the exquisite forms which are the types of this class, and which, like animated flowers, may be seen expanding their sensitive petal-like tentacles in search of the materials that constitute their prey. On the retreat of the tide those that are left uncovered by the water contract, and appear as little, rounded, firm, gelatinous masses, attached to rocks and stones by means of a flat suctorial disk.

FIG. 25.



Vertical section of common Sea anemone, *Actinia mesembryanthemum*.
m mouth, *m'* primary mesentery *m'* secondary mesentery, *e* ectoderm, *e'* endoderm, *t* tentacle, *t'*, ovary, *d* disc of attachment, *s* body-cavity.

The body of one of these when expanded is somewhat cylindrical, having a free extremity which bears the mouth, and an attached end, which is usually capable of voluntary detachment. This extremity is sometimes called the foot. On making a transverse section the body appears like a double tube; the outer tube is the body wall, the inner bounds the stomach, and between them is the body-cavity into which the stomach-sac opens below by a narrow aperture.

The body-cavity extends upwards into the hollow tentacles, each of which is in fact a tubular prolongation continuous with this cavity. In life, when the body is expanded, the space between the stomach and the body wall contains sea-water which also inflates the tentacles, but on irritation the contraction of the outer wall drives out this fluid, which escapes in minute jets through the terminal pores at the extremities of the tentacles.

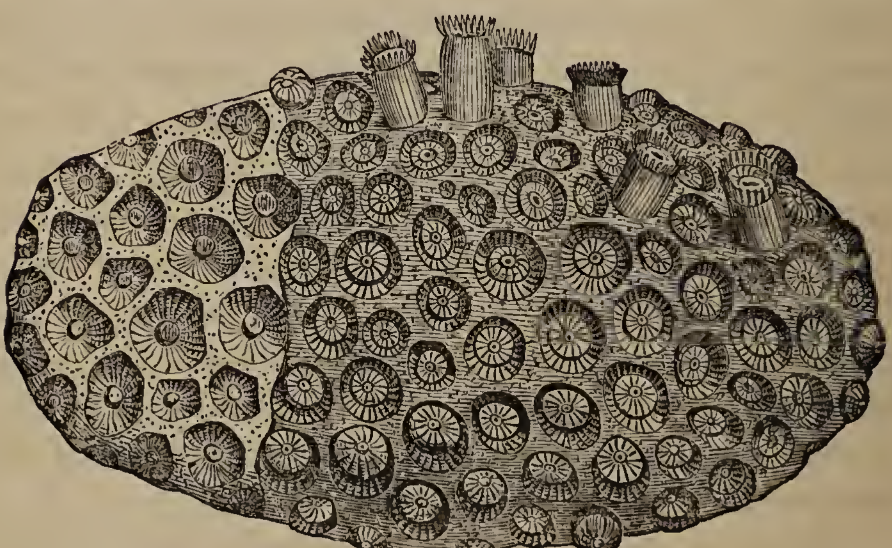
The body cavity is divided by vertical partitions which pass inwards to the outside of the stomach-wall, and thus divide the outer chamber into a series of smaller compartments which radially surround the stomach, below which they all communicate with each other. There are five or six such large partitions extending for the whole length of the body wall, which are called *primary mesenteries*, and between them are smaller partitions in equal numbers, called *secondary mesenteries*, between these, there are often still smaller *tertiary mesenteries*, twice the number of the primaries, and in some related forms other orders of intermediate partitions exist, still farther sub-dividing the body cavity, but each set shorter than its predecessors.

The outer surface of a sea anemone, and especially of the tentacles, is richly covered with thread cells, which, when burst, are sometimes thrown off as a continuous slough. This can be seen when an anemone is imprisoned in a bottle of sea-water, and in the same condition we notice that as the water becomes less able to support the life of the creature from its loss of oxygen and of material for food, that the body becomes enormously swollen by the inordinate amount of water which the anemone takes in.

Multiplication. — Sea anemones occasionally multiply by division, but, in general they increase by the development of eggs, in the thick cord-like edges of the mesenteries. These eggs are emitted by the mouth, and from them arise minute, ciliated embryos which become saccular.

Anemones can be multiplied also by artificial division, and if an anemone be cut horizontally the mouth end still continues to eat, and finally develops

FIG. 26.



Caryophyllia fasciculata, a sclerodermic coral. The left side of the figure shows the coral denuded of soft parts; on the right the animal matter is shown, while at the upper part several of the polypes are seen projecting.

a foot, while the foot end may (but seldom does) continue to live and may ultimately develop tentacles. One experimenter produced by his sections an anemone with a tentacle-armed mouth at each end.

Corals and Coral Building.—Most sea anemones are solitary ; a few only form colonies by continuous budding, and by the formation of a uniting cœnosarc. In sea anemones proper, there is no deposition of an indurating material, but in tropical seas a closely allied group of animals abstract lime from the sea-water, and lay it down in one of two ways, either in the animal's tissues, or else in the centre of the cœnosarc, and *around* the body, *outside* the foot of each separate polyp. Hard masses thus formed are called *corals* ; and all the reef-building corals, the Madrepores and Oculinas, are examples of the former kind, or tissue-depositions. The deposit may be in the body wall, in the mesenteries of the polyps, or in the cœnosarc. Growth in these colonial forms takes place either by the formation of buds which remain continuous and may spring from various parts of the original stem, or else by fission, but in this case the new polyps remain connected together. Owing to these different modes of growth there is much variety of shape and structure among the hard parts of different corals. Large masses of coral, which are called reefs, are usually found in the seas of such climates as have a winter average temperature over 60° F. and where the water is clear, and not mixed with mud or fresh water. They abound chiefly between the depths of 1 and 50 fathoms, and vary in form according to the shape and condition of the sea-bottom.

A few of the coral-building animals are solitary, like the little *Caryophyllia* of European seas. Some of the commonest forms of corals brought to this country from the tropics are the mushroom-shaped lamellar *Fungiæ*, the richly perforated Madrepores, and the brain-corals, or *Mæandrinæ*.

Sub-Class 2. Alcyonaria.—The sea often casts on the shore large, yellowish, gristly masses, known by the fishermen as 'dead men's fingers,' but technically named *Alcyonium*, which are types of the second sub-class of Actinozoa. On placing this *Alcyonium* in sea-water the surface sends forth from each pore a little crown of tentacles. These are seen to be in circlets around the mouths of minute polyps, and they differ from the tentacles of sea-anemones in two respects; first, they are in multiples of four, usually being eight in number, and, secondly, they are pinnately fringed, that is, evenly toothed and lobed around the margin, each little tooth having a hole at its tip: otherwise the organisation is of the same type as that of a sea anemone. Minute calcareous spicules are abundantly scattered through the mass, and in some allied forms, these, together with hard horny matter, make up a continuous, coral-like, foot-secretion in the axis of the cœnosarc, as in the fan-corals or *Gorgonias*. In the precious red coral of the Mediterranean, this axis is of stony hardness; and in *Isis*, calcareous and horny joints alternate with each other in the central axis of the stem, thus combining firmness and flexibility. The red organ-pipe coral of the Indian Ocean, with its table-like partitions and its green polyps, belongs also to this group. The feather-shaped sea-pens, which are nearly related to the Gorgoniæ, are not rooted, but have the extremities of their stems buried in sand.

Recapitulation.—All the animals which make up the sub-kingdom Cœlenterata show a radiated arrangement of parts, the bodies being formed of a series of symmetrical segments around a central axis. In all of them, the body wall of each individual animal is made up of two membranes, an outer and an inner; all are aquatic, and, with about four exceptions, marine. They all have a central stomach, a mouth at one pole, surrounded by tentacles which are armed with *thread-cells*, these latter being almost universal in the sub-kingdom. When a nervous system exists it is as an obscure ring, and is related to the margin at the base of the tentacles.

The two great classes of Cœlenterates, Hydrozoa and Actinozoa may be contrasted thus: the former have but one internal cavity; the latter have a central stomach cavity surrounded by a separate, though communicating body cavity, and the egg-producing organs open into this second space.

The two great sub-classes of Actinozoa are—

A, Those with simple tentacles in multiples of 5 or 6: Sub-class 1, Zoantharia.

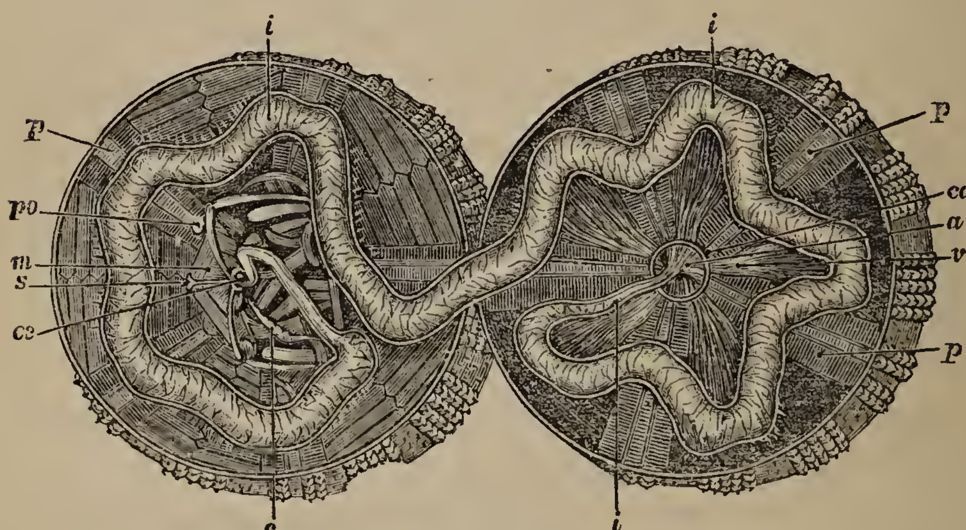
B. Those with pinnate tentacles in multiples of 4: Sub-class 2, Alcyonaria.

CHAPTER IX.

SUB-KINGDOM 4. ECHINODERMATA: ENCRINITES AND STAR-FISHES.

General Characters.—Sea-urchins, star-fishes, and sea-cucumbers make up a natural assemblage of animals, called *Echinodermata* on account of the spiny skins found in most species. They display a radiating symmetry, but either in the larval or in the adult condition there are traces of a bilateral disposition of parts. A body cavity is always present, containing within it the digestive organs, and the stomach cavity never communicates with this surrounding space in the perfect or adult animal, as it does in the Cœlenterates. The Echinoderms possess a nervous system of radiating

Fig. 27.



Section of the purple Sea Urchin (*Strongylocentrotus lividus*): *a*, anus; *œ*, œsophagus; *i*. intestine; *s*, one of the rods of the tooth apparatus; *m*. muscles of the jaws, *p*, vessels of the sucking feet; *po*, extremity of the water vessel; *ca*, ocular plate; *v*, ovary.

threads, united by a ring of nerve-matter around the mouth, and some of them exhibit pigment masses, which are supposed to be simple eyes containing the ends of nerve fibrils embedded in them. Calcareous matter is deposited in the skin, either in the form of spicules, or of plates which, by being jointed together, build up a shell or outer 'test' for the body.

When one of our common Echinoderms is put into a vessel of sea-water, locomotion can be seen to take place by means of numerous little tubular processes which project through holes in the surface of the shell each of them ending in a little sucking disk. There are five pairs of rows of these feet in most species, and these, by attaching themselves and then contracting, draw the body of the animal along. Each of these *pedicelli*, or little feet, as they are called, is hollow, and contains sea water, and there are five long tubes in each Echinoderm, which pass meridionally, and by fine vessels convey the fluid into the pedicelli from a tubular ring which surrounds the mouth. To the tubular system which supplies the little feet, the name *Ambulacral* system is given. This arrangement of water-vessels connected with locomotion is peculiar to echinoderms. The sub-kingdom consists of four chief classes.

Class I. **Encrinites (Crinoidea).**—These animals abounded in former times in the seas of our globe, but they are now for the most part extinct. The name is derived from the resemblance of many of the fossil forms to the flower of a lily, the infolded arms having a petal-like appearance. With a few exceptions, they are not, in their adult state, free and capable of locomotion, as are all other Echinoderms, but are fixed on a jointed calcareous stalk. Though when first hatched from the egg all Crinoids are free-swimming ciliated bodies, yet very soon they settle down, develop a stalk, and become rooted (fig. 28). There is a central mouth, surrounded by a circle of movable arms, which are often branched, and between these arms are little plates pierced by holes through which the ducts from the egg-producing organs open. In general appearance these Crinoids look like star-fishes fixed on central jointed stalks, and they are furnished with feathery ambulacral feet on their upper surface, which as they cannot serve for locomotion seem to act as gills for breathing. The commonest of the living Crinoids

FIG. 28.

Embryo of the Feather Star, showing its stalked, encrinite-like stage.

FIG. 29.

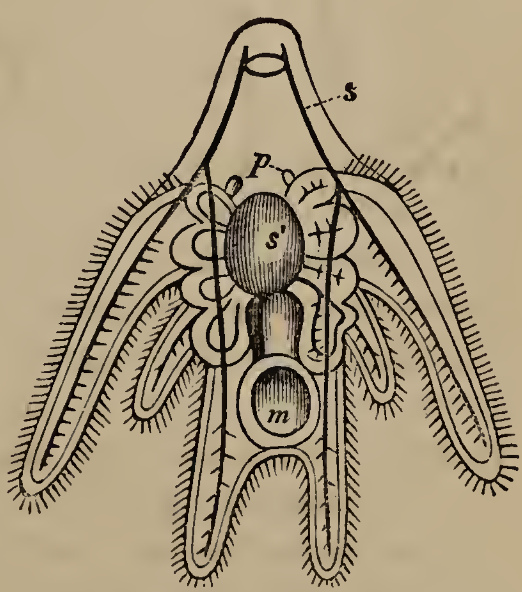
Rosy Feather Star (*Antedon rosaceus*), adult or free condition.

becomes free in its adult stage, and has a singular history. Beginning its life as a free-swimming embryo, it soon becomes fixed, and appears as a stalked organism (fig. 28), but, after existing in this state for a short period it loses its attachment, becomes free, and forms the exquisitely tinted rosy feather star, with ten to forty arms, found in our seas.

CLASS II. **Starfishes (Stellerida)**, (fig. 3, p. 7).—The form of the animals of this class is expressed by the name. They all possess a central disc from which five to twenty arms radiate. The surface is generally roughened with stiff ridges and spiny points, and under this layer is a layer of calcareous plates; each arm has on its under surface a groove in which lie the ambulacral vessels, and the nerve-cord; and many starfishes have imperfect red eyes at the end of this ambulacral groove.

On our sea-shores there are two kinds of starfishes to be found, the first kind or Brittle-stars have a rounded, or five-sided flat disk at the centre, and slender, jointed, snake-like arms, which, as they do not contain processes of the viscera, the animal can break off when irritated. These brittle-stars chiefly are found on seaweeds. The other and commoner kinds of starfishes have thick, flattened triangular arms which are continuous with, and not jointed to, the disk. These have a mouth in the middle of the under surface of the body, and around it on the skin are curious little spines whose extremities are movable, and two- or three-bladed, like little pincers. To these little grasping organs, which assist in seizing the prey, the name

FIG. 30.



The larva or pluteus of the Brittle-star (*Ophiolepis*).
m, mouth; *s*, stomach; *s*, calcareous skeleton.

pedicellariæ ('little feet') is given. From the central stomach, which communicates directly with the mouth, long blind pouches extend into the arms (usually two pouches into each arm) thus increasing the size of the digestive sac. There is an ambulacral ring around the mouth, and radial vessels extend from it into the arms to supply the little feet; and to convey sea water into the central ring there is a canal, usually filled with sand, which starts on the dorsal surface of the disk from a spot where there is a wart-like, finely perforated plate, which from its likeness to a piece of coral is called the *madreporiform plate.* Through it, as through a sieve, the sea-water filters into the sand-canal, and thence into the ring around the mouth.

Besides the ambulacral vessels, there exist in starfishes fine vessels on the surface of the digestive cavity, which unite to form a second vascular ring around the mouth; this second system is one of blood-vessels directly concerned in the nutrition of the body. The larvæ of starfishes, on leaving the egg, appear very dissimilar from the adults, looking like little easels, and are hence called *plutei* (fig. 30); those of the brittle-stars have a delicate calcareous skeleton, which is wanting in those of the common five-fingered starfishes, which in many respects seem to resemble the comb-bearing Hydrozoa. In their adult states these starfishes move mouth-downwards and are extremely voracious, attacking molluscs, dead fishes, and other kinds of animal matter in the sea.

CHAPTER X.

SEA URCHINS AND SEA CUCUMBERS.

CLASS III. **Sea Urchins (Echinoidea).**—The globular or heart-shaped sea-eggs, found along our sea coasts, are representatives of the next group of Echinoderms. In these the surface is covered with movably jointed spines, each of which shows on section a beautifully reticulated structure which varies in each species and the attached end of each spine is hollowed to fit on a tubercle (fig. 27, p. 48) on the hard shell beneath, with which it thus forms a ball-and-socket joint. On removing the spines there is found under them a shell composed of numerous flat angular plates, arranged in meridional rows. This shell has the mouth at one pole, which in the living animal is undermost and the excretory orifice at the opposite extremity; and from mouth to apex the shell is divided into ten meridional segments, five of which consist of plates pierced with holes for the ambulacral feet, and five of unperforated plates; these are placed alternately, and each segment, perforated or unperforated, consists of two rows of plates (fig. 31, *a*, *b*).

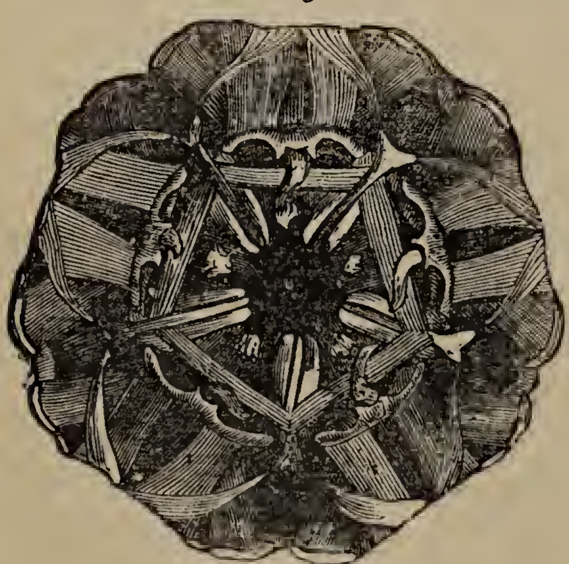
FIG. 31.

The apical end of the shell of *Echinus esculentus*. *e* anal opening, *c* ocular plates, *d* ovarian plates, *b* madreporiform plate.

The mouth is surrounded by a soft area of skin bearing modified spines, modified tube-feet and pedicellariæ, somewhat like those of starfishes ; the opposite or aboral pole is surrounded by five plates, each placed at the end of one of the imperforate meridians, and each pierced by the end of the duct from one of the five large egg-secreting glands which lie within the shell between the ambulacra. Between these ovarian plates and at the end of the ambulacra are five smaller plates, each pierced by the end of the radial nerve threads, and bearing a little eye-speck; these are called 'ocular plates.' One of the former set of plates is always unsymmetrical, swollen, and finely pierced with holes, being in fact the combination of an ovarian plate with the madreporiform tubercle at the end of the sand canal as in starfishes.

Sea Urchins have ambulacral vessels just like those of starfishes, with a tubular ring around the mouth and five branches, one along the inner surface of each set of perforated plates, through the holes in which the tube feet project.

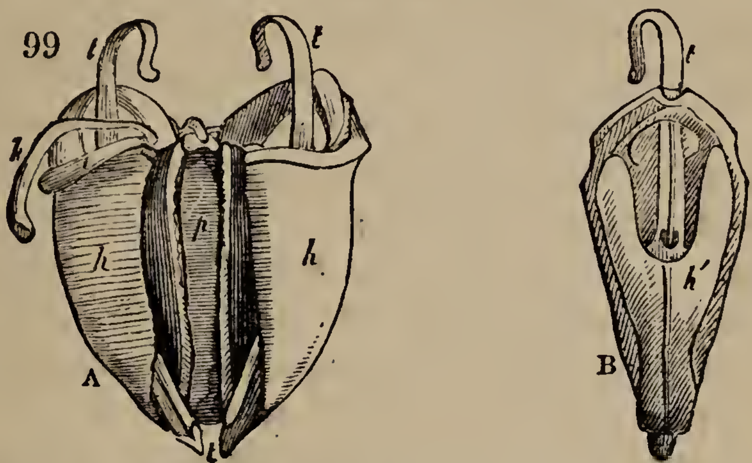
FIG. 32.



Tooth apparatus of the Sea Urchin, showing the arrangement of the muscles.

Most Sea Urchins have the mouth armed with a complex system of teeth, five of which are placed around the orifice with their points directed towards it, each being situated in the centre of a wedgeshaped jaw (fig. 33), which itself consists of two symmetrical halves. Twenty-five accessory pieces are appended to these parts, and the whole apparatus is moved by thirty muscles (fig. 32). This apparatus is fixed by

FIG. 33.



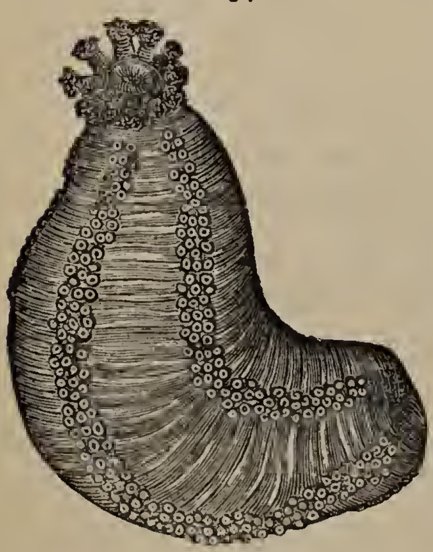
Jaws of the Sea Urchin. A, two jaws seen laterally ; B, interior view of a single jaw ; *h*, surface of jaw ; *t*, teeth.

muscles and fibrous bands to calcareous loops which project inwards at the mouth end of the shell, and it can easily be dissected in the common sea urchin. The larvæ of sea urchins are pluteus-like, containing a calcareous skeleton.

Two types of sea urchins are found in American seas. One like the common *Strongylocentrotus drōbachiensis* is globular or slightly flattened, with ambulacral areas extending from pole to pole, and with the mouth and anus at opposite poles ; the other type, represented by the heart-urchin (*Schizaster fragilis*) found in deep water, has the anus not opposite to but approximated to the mouth, and the ambulacral rows not extending from pole to pole, but in petal-like areas on one surface of the shell alone.

Class IV. **Sea Cucumbers (Holothuroidea).**—Singular, elongated or cylindroidal animals, closely allied to sea urchins, but without either spines or hard test, make up this class. They are found among the tangles or in moderately deep water along our shores. The body-wall is muscular, and contains in its surface-layer calcareous spicules, resembling anchors, wheels, &c. The mouth is surrounded by plumose tentacles, and, on the surface of the body are rows of tube-feet, more irregularly disposed than in sea urchins. The intestine is often of great length, and ends in a small aboral sac or cloaca, into which also open (in most species) two very remarkable tree-like organs which lie in the body cavity, and which are adjuncts to the water-vascular system for purposes of breathing. In organisation they resemble sea urchins, and often reach very large sizes. In tropical seas some of these Holothurians are inhabited by little parasitic fishes, and even in temperate regions small shelled mollusks are found in or on their bodies as parasites. One species, the Trepang, is imported in large quantities from NE. Australia into China, where it is regarded as a luxury of diet.

Fig. 34.



Cucumaria doliolum. One of the Sea Cucumbers.

Recapitulation.—Echinoderms are characterised by the presence of highly differentiated tissues, a distinct nervous system, a digestive canal which in the adult is separate from the body cavity (though in the embryo, the body cavity arises as an outgrowth from the primary intestine), a radiating symmetry tending to become bilateral, and a water-vascular system whose little tubular feet or offsets act as locomotory feet.

The chief sub-types may be tabulated thus—

A. Body stalked at some period of life, ambulacral feet not locomotory = Class I. Crinoidea (mostly fossil).

B. Never stalked, star-like, with ambulacra as organs of locomotion. = Class II. Stellerida.

  a. Arms jointed to the disk, not containing viscera = Order I. Ophiuroidea (Brittle Stars).

  b. Arms not jointed, containing viscera = Order II. Asteroidea (common Starfishes).

C. Never stalked, globular, disk-like or heart-shaped, with a continuous test = Class III. Echinoidea.

D. Never stalked, elongated, with a soft integument containing spicules = Class IV. Holothuroidea.

The Echinodermata are all marine, and are never united together into colonies.

CHAPTER XI.

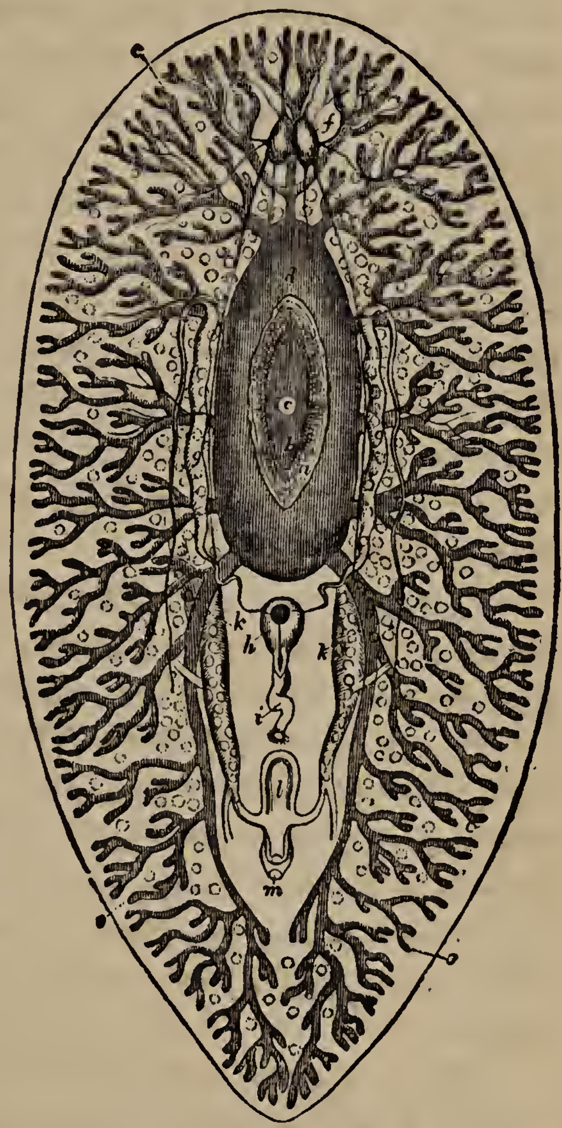
SUB-KINGDOM V.: VERMES.

Worms, though often mean and uninteresting in external appearance, are yet in many respects among the most curious forms in the animal kingdom. They are elongated, soft-bodied creatures, which have their organs arranged in a bilaterally symmetrical manner. In many of them the body consists of successive segments, arranged in a chain, each intermediate segment being like its preceding and succeeding neighbours. There is a nervous system in most forms, consisting of two or more nerve knots above the pharynx and a cord prolonged backwards along the under side of the body, beneath the digestive canal. A water-vascular system exists in some form or other in all worms, but it has never any connexion with the function of locomotion. It usually consists of a system of tubes, one in each of the successive segments of the body, opening by one extremity on the surface and by its other end communicating with the body cavity. These sets of tubes are commonly known among the higher worms by the name of *segmental organs.* Blood-vessels often exist, and sometimes contain coloured blood, but there is no heart, and the colour does not depend on the existence of minute floating coloured corpuscles in a colourless fluid, as is the case with the blood of vertebrates. The common earth-worm and leech may be taken as well-marked examples of the sub-kingdom.

Many worms are parasitic and live within the bodies of higher animals; among these the circulatory, water-vascular, and digestive systems become rudimental, the nervous system remains undeveloped, the body cavity often vanishes, and the reproductive organs alone are fully represented. This sub-kingdom includes the following classes:

CLASS I. **Turbellaria.**—The simplest worms with which we are acquainted are found on the sea-shore, under or adherent to stones, or else in fresh water pools, as small ciliated, flattened soft bodies, which glide with a slug-like motion over wet surfaces, or swim by the vibrations of their cilia. These *Turbellarians* (so called from the commotion produced by their cilia in the water around them) have a mouth placed generally *beneath*, not *at* the anterior extremity, and the part of the digestive canal immediately within the mouth is protrusible as a kind of proboscis. This contains, in some of the larger forms, a spine or dart, which is used as a weapon of offence, and being supplied with poison from a little poison-gland at its base, acts as a formidable weapon against the minute creatures upon which these animals feed. The digestive canal

FIG. 35.



Polycelis lævigatus, a common Turbellarian.

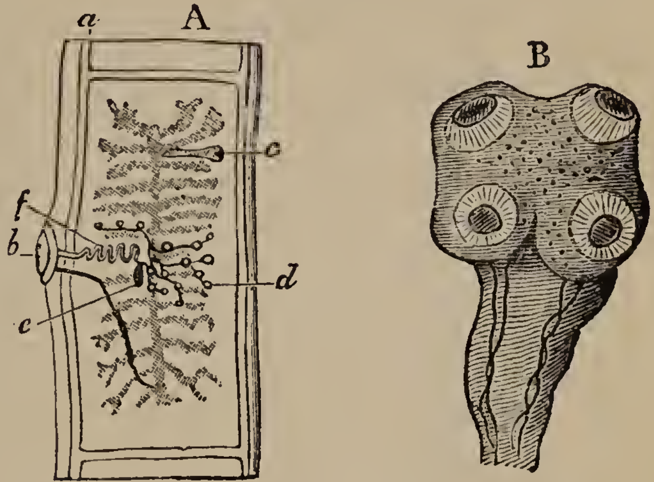
in the smaller flatter forms is often tree-like, branched (fig. 35). In others it is a simple pouch with no excretory orifice, but in the larger forms it is elongated. The water-vessels appear as two lateral tubes, and the egg-producing organs are usually complex. The young Turbellarians on leaving the egg are usually unlike the parent, often helmet-shaped, with a whip-lash-like process at the apex, but this larva develops into a worm-like body by moulting or shedding its surface. The smaller forms are generally flattened, somewhat elliptical; the largest are worm-like, sometimes very long, and are called Nemertean worms. One of these, Borlasia, found not very uncommonly on our own shores, has been taken measuring twelve feet in length.

The 2nd, 3rd, and 4th classes of worms are mostly parasitic in their habit and are called suctorial, round, and thorn-headed worms respectively.

CLASS II. **Cotylidea.**—The sucker-bearing worms are so called because they are armed with rounded or irregular cup-like suckers. These worms are generally simple in organisation; and their body cavities and digestive organs are either abortive or rudimentary. The two types of these worms are *Tapeworms* and *Flukes*.

The tapeworms are so called from their great length and flatness. They exist principally in the digestive canals of higher animals, especially in fishes. The human race is not exempt from occasionally harbouring at least three species of these parasites. One of these, the common tapeworm, or *Tænia solium*, is common in Britain and Western Europe, and may be taken as the type of the order. On examination, it presents to us a very small roundish head armed with twenty-six little hooks arranged in two rows, and four round suckers, followed by a long slender neck, at first undivided but soon exhibiting traces of transverse segmentation, which, as we trace the worm from the head, become more and more clearly marked until we reach a part consisting of distinct joints, each of which joints contains a complete egg-producing apparatus.

FIG. 36.



A, Proglottis, or perfect joint of Tapeworm (*Tænia solium*); *a*, water-vascular tube; *c*, egg-producing organ. B, Head of *Tænia mediocanellata*.

When we remember that these worms may attain the length of 25 feet, and that there are at least twenty perfect joints in a foot, and that each joint can produce many scores if not hundreds of ova, we can form some idea of the amazing fecundity of these parasites. The growth of the individual takes place from the head, so that the oldest segments are those which are most remote from it and the newest are the fine joints close thereto.

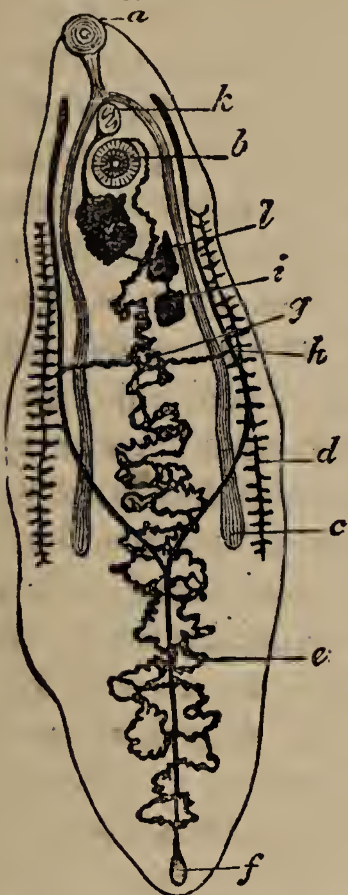
The life history of the tapeworm is curious. The eggs are protected by a very firm horny capsule and thus they can maintain their vitality for long periods of time, and can resist maceration and even short exposures to high temperature. On entering the digestive organs of some animal with its food or drink, the embryo is set free and travels through the tissues of its new host as a little oval body armed in front with weak hook-like or boring spines. On reaching a suitable site it anchors, and the body dilates into a sac full of water. In this cystic condition the animal may remain stationary for a length of time, and by budding the number of cysts is capable of a rapid increase. When the flesh of an animal containing such cysts is eaten by another, the liberated saccular worm has its outer wall dissolved away, and its inner portion lengthens and in a short time becomes a true tapeworm. In most cases it requires two animals as hosts for the proper perfection of the worm. Thus the human tapeworm has its cystic stage in the flesh of the pig, the condition of pork called 'measly' being due to these little cysts in the muscles of the pig. Similarly, the tapeworm of the dog develops from cysts found in the hare; that of the cat from cystic worms in the mouse, that of the fox from cysts in the field-mouse, &c.

In Ireland, the commonest human tapeworm has four suckers but no hooks on its head (fig. 36 B), and is known as *Tænia mediocanellata*; its larva inhabits the ox.

In Russia and Switzerland, the human tapeworm is quite a distinct species, with very flat body, no hooks, and two long grooves on its head in place of suckers; its larvæ live in the waters of certain lakes, and it has been supposed that it is through these waters being used for drinking purposes that they gain entrance into the human body.

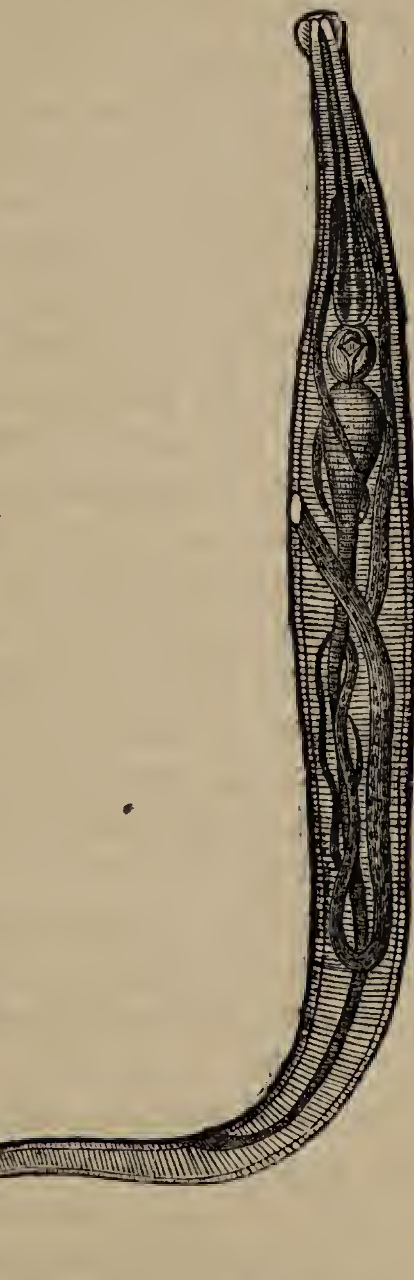
Trematodes or Flukes.—The second order of sucker-bearing parasitic worms consists of the 'flukes,'

FIG. 37.



Distoma lanceolatum, the liver fluke. *a*, mouth ; *b*, sucker ; *c*, digestive canal; *d*, *e*, water-vascular system ; *h*, *k*, reproductive organs.

FIG. 38.



Oxyuris vermicularis, the common threadworm of children.

met with in the liver of the sheep, and of allied forms (fig. 37) ; these are not united in chains as in the tapeworms, but each consists of a single segment bearing one or two suckers (*a*, *b*). In many respects they resemble the Turbellarian worms, but are not ciliated and often present formidable armatures of recurved hooks. They are like tapeworms in the development and complexity of their ovaries, and many of them show in their history alternations of generations as curious as those of their relatives the tapeworms; for example, the larvæ of some liver flukes live for a time free, in water, and develop within their bodies little cylindrical worms, which are set free on the bursting of the wall of the parent, and in turn enjoy an independent life. Within these worms again there may form another brood of internal buds, which also grow, burst their envelope, and become for a time free, but soon attach themselves to some soft aquatic animal in whose body they become encysted, to develop finally into the mature forms when their first host is eaten by some larger animal. Thus the flukes found in water-fowl have their larvæ in water molluscs, &c. To these flat sucker-bearing parasites the name *Trematoda* is given.

Class III. **Nematelmia.**—These, the commonest forms of parasitic worms, are cylindrical, tapering to each end, and possessing a body cavity (fig. 38.) They are never divided into successive joints, although their surface may be finely ringed, and there is always a digestive canal with an outlet, as well as a mouth.

The round worm, often found in the small intestines of children, is a good example of the order. It is about seven or eight inches long, ringed on its surface, with the mouth at its anterior end, surrounded by three little lobes; from this, a tube, the *œsophagus*, passes to the stomach, which is a small suctorial muscular cavity, communicating by a straight intestine with an outlet which is not terminal. Beside the common round *Ascaris lumbricoides*, the human digestive canal is the occasional dwelling-place of two other worms, one of which, *Oxyuris vermicularis*, is a small thread-like worm (fig. 38), the other *Trichocephalus dispar*, much more common, has a very slender neck and a thicker body. A species closely allied to the last named is the *Trichina spiralis*, a minute worm found in the flesh of pigs, calves, &c., which when introduced into the human body, often multiplies rapidly in the voluntary muscles of the system, causing dangerous and even fatal symptoms.

These worms are as prolific as their fellow parasites, and the early stages of many live for a time in water, from whence they enter into the bodies of their hosts, and in those whose life-history we know, the free and parasitic conditions appear very dissimilar. It has been supposed and with reason that most of the free Nematelmians found in stagnant pools are early stages of parasitic species.

Gordiaceæ. — The horsehair-like thread-worm which is found in rainwater pools is an example of a second order of round worms. This remarkable animal begins life as a little larva living in mud or in water pools; it is armed with boring spines, whereby it pierces into the body of a beetle or other aquatic or terrestrial insect; here it becomes encysted, and, having grown in this condition to a considerable length, often ten times as long as its host, it becomes free and aquatic and produces its eggs. So rapidly do some of these multiply, as, for example, the common *Mermis albicans*, that they have given rise to the belief that they have fallen as 'worm-rains.' These worms are called Gordiaceæ and are distinguished from the other round-worms by the rudimentary condition of their digestive canal. They are also remarkable for their extreme tenacity of life, as they can be dried into hard brittle threads and yet appear lively and active on being moistened.

Class IV. **Acanthocephala.**—The 'thorn-headed' worms are rounded, or cylindrical, each with a protrusible proboscis armed with many recurved hooks. They are remarkable for the total absence of the mouth and intestine in their adult condition. The commonest species are found in the intestines of swine, &c., with their heads buried in the substance of the wall of the digestive tube.

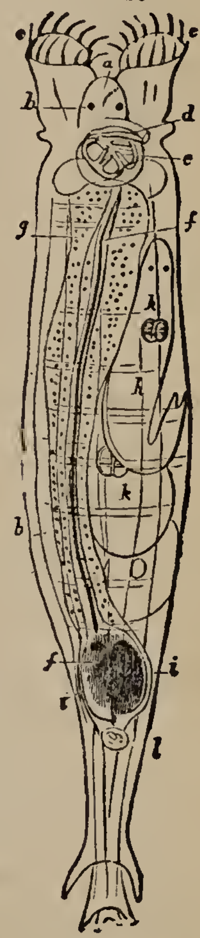
CHAPTER XII.

NON-PARASITIC WORMS.

Class V. **Wheel-Animals, Rotatoria.**—On tracing the development of the more complex free worms we find that the larva, after emerging from the egg, appears as a free-moving creature, with circlets of vibrating cilia around its extremities, these ciliary lobes being in some forms large and rounded (fig. 47, A).

In rain pools and ditches, small creatures are frequently met with which resemble the larvæ of worms, but which remain permanently in this ciliated condition. In these, the ciliary lobes are prominent and rounded, acting as locomotory organs, and from the rapid vibration of the cilia which clothe them they seem like rotating wheels, hence these little creatures are called *Rotatoria*. They are microscopic in size varying from $\frac{1}{500}$th to $\frac{1}{9}$th of an inch in length, but from the exquisite transparency of their bodies the details of their organisation can be seen by the aid of the microscope. The male rotifers are few and small and have no digestive canal; the females have a complex nutritive system, and many species are provided with an organ of mastication like an anvil acted on by two hammers. These animals can bear much ill usage, and are capable of reviving again on being moistened, after having been almost completely dried up.

Fig. 39.

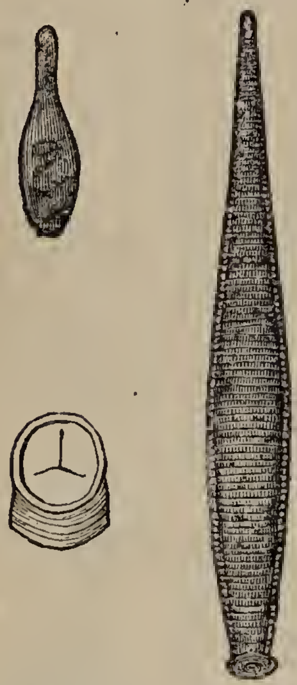


Rotifer vulgaris.

On irritation the trochal disks (fig. 39, *c*) can be retracted into the cavity of the body, from which they are gradually protruded again on the cessation of the stimulus. Some rotifers are rooted; others possess a forceps posteriorly, whereby they can hold on to foreign bodies; others again are contained in a vase-like sheath, into which they can retract themselves, on being irritated.

Class VI. **Spoon-worms** or **Squirt-worms, Gephyrea.**—These are interesting marine worms whose elongated or sac-like bodies contain a long tortuous intestine, ciliated inside and outside. They rarely exhibit a division into segments, nor have they locomotory processes of any kind, and they never have any calcareous

FIG. 40.



Embryo Leech. Adult Leech.
Mouth of Leech.

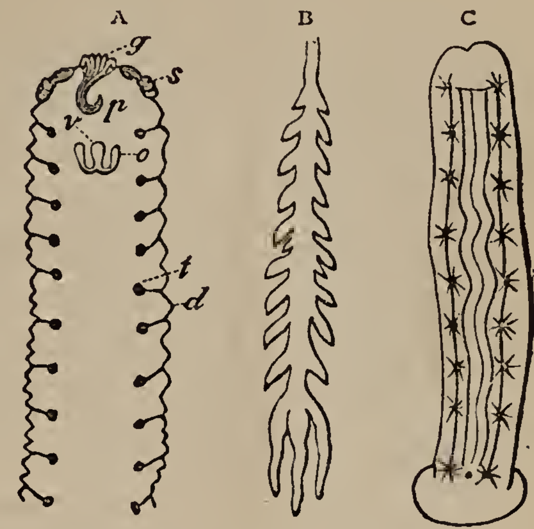
FIG. 41.

Tooth and Muscles of Leech.

or siliceous spicules in their skin, although sometimes there are a few bristles scattered on the surface. The mouth is at the anterior end, and it is provided with a protrusible proboscis, sometimes of great length.

CLASS VII. **Leeches.**—The next group of worms is exemplified by the common horse-leech or by the medicinal leech. They are soft-bodied annulated worms which live parasitically on the outside of vertebrated animals, from which they draw their nourishment. Their bodies are composed of segments, which are indistinctly or not at all marked from each other on the surface, but can easily be distinguished within, as the organs of the body are arranged in successive groups. Leeches have at their front end a sucker, and some have a second suctorial disk at the hinder extremity, and several species are even provided with lateral suckers. The mouth is generally situated in the front sucker, and it is armed with three horny jaws or plates (fig. 41) with serrated edges. These plates act as teeth, enabling the leech to make incisions in the skin of its host through which to suck the blood. The digestive canal is straight and consists of a central tube with a row of blind pouches along each side (fig. 42, B) which can become distended, hence the body can take in a great quantity of blood.

Fig. 42.



A Reproductive organs of leech. B Digestive canal of leech. C Nervous system of Malacobdella.

There is a nerve-ganglion in each segment of the body, the first (fig. 42, C) of these is comparatively large and made up of several smaller ganglia grouped together; the successive ganglia are united into a chain by fine filaments and they lie on the ventral or under side of the digestive organs.

Leeches possess proper blood-vessels in which their own nutritive fluid circulates. Their water-vascular system takes the form of a series of *segmental* *organs* or tubes opening laterally, one on each segment. The egg-producing organs are very complex.

Locomotion takes place by the suckers: the hinder one being fixed, the animal elongates itself and, fixing its front sucker, sets free the hinder one, then shortening its body it proceeds in a similar manner. Leeches can also swim, and when so progressing the body becomes flattened by the contraction of vertical muscular fibres which run from the dorsal to the ventral surface, and then by undulating movements it advances like a wavy ribbon.

Medicinal leeches are principally imported from Hungary and Sardinia.

CHAPTER XIII.

NON-PARASITIC WORMS.

Class VIII. **Bristle-footed Worms (Chætopoda).**—We can scarcely turn over a stone on the sea shore

Fig. 43.

Transverse section of a Worm, of Amphioxus, and of a Vertebrate contrasted. *a*, outer or skin layer; *b*, dermal connective layer; *c*, muscle plates; *d*, segmental organ; *h*, arterial, and *i*, venous blood-vessel; *g*, intestine; *l*, notochord.

without finding under it some species of the group of bristle-bearing worms, a class of which the lug-bait or the hairy-bait of fishermen may be taken as representatives. These worms have bodies made up of a succession of similar joints, and their locomotion, either creeping or swimming, is accomplished by means of little stumpy bristle-bearing eminences, with which their bodies are provided. Each joint of the body exhibits two pairs of these processes, two of which are on the upper or dorsal surface, and two are on the ventral or under surface, one on each side of each surface; these are known as dorsal and ventral oars. The mouth is on the second segment, and is often armed with sharp teeth. The intestine is usually straight and very often has lateral pouches appended to it like those in the leeches. There is a vascular system consisting of long tubes, dorsal, ventral and lateral, and the blood contained in these is often red, green, or white. The gills are usually arranged along the dorsal surface of the body springing close to the root of the dorsal oar, and in these the blood is purified by being exposed to the oxygen held in solution in the sea-water.

FIG. 44.

Arenicola piscatorum
Lug-bait worm.

There are also segmental tubes opening one on each side of each segment, and sometimes the eggs, which are produced within the body, escape through these canals. The chain of nervous ganglia is also well-developed. Some worms secrete a glutinous material from their surface, which cements together sand-grains and other foreign bodies into a tube wherein the animal lives. Other worms secrete from their surface calcareous matter which makes up a tube as a dwelling-house, in which the animal is permanently contained. Such forms have the gills developed only on the foremost segments of the body, and have the dorsal and ventral oars of all the other joints rudimentary; but they possess tentacle-like, branching processes about the head. Of these the common Serpula, whose white calcareous snake-like concretions are so common on the stones and shells on the sea shore, and the Spirorbis, whose minute white whorled shells dot the surface of the shore-tangles, are examples.

A few worms are phosphorescent; many others, ike the sea-mouse, are clad with iridescent scales and bristles.

The common earthworm has much smaller and fewer bristles, which are in the form of recurved hooks, not elevated on stumpy processes of the surface. The body is closely ringed and tapers from the middle forwards to an acute point in front. Each ring bears its armature of hooks, which can easily be felt by drawing the body of a worm between the fingers from tail to head, although they are scarcely to be detected when we feel the body in the reverse direction. In beginning to burrow, the worm lengthens its body and pushes its sharply pointed head into the mass of soil which it is about to perforate, then having insinuated the few foremost rings of its body into the mould, the whole animal contracts in length, thus swelling the front of the body in thickness and forcibly dilating the opening made by its fore part, the worm being prevented by its hooks from slipping out of the opening; then it again lengthens its body in front, its hooks giving it a fixed point from which to act, and by a succession of such elongations and thickenings it can 'worm' its way through even a hard gravel walk.

The mouth of an earthworm is placed on the second segment, near the apex of the body, and from it the digestive canal extends as a straight tube through the body. This tube is very wide and is always found full of earth, as these animals devour large quantities of the soil for the sake of the organic particles contained in it, the remaining part being passed out, and heaped by the worms at the outlet of their burrows, as 'worm casts.' For the better division of the material swallowed, the digestive canal is provided with a muscular gizzard about fifteen rings behind its mouth.

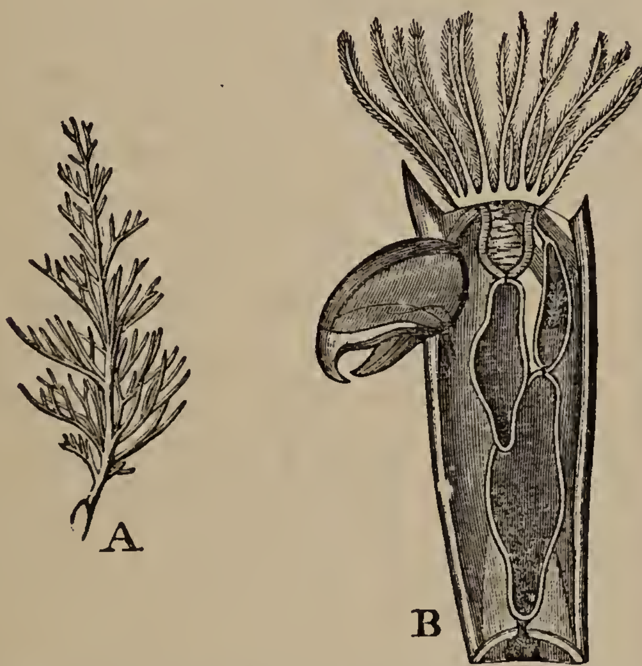
The eggs in earthworms are produced in the body cavity beginning at a point about seven rings from the mouth, and they usually fill the body for about seven segments. distending it and producing a thick white band or ring which we often notice in the body of worms during early autumn. Worms are propagated exclusively by eggs, the common belief that, when cut in pieces, each part is capable of independent life not being strictly true. If we divide an earthworm about its middle, the hinder segment dies after a short time; the fore segment will probably live and its wound heal. Similarly, if we cut the anterior four or five segments away the small fore fragment will soon die, while the large hind mass will recover.

CHAPTER XIV.

MOSS POLYPS AND TUNICARIES.

CLASS IX. **Moss Polyps (Bryozoa).**—The broad leathery fronds of the tangles along our shores are often encrusted with beautiful lace-like patches of regular and minute patterns. If we put a fresh, living piece of this into a vessel of sea-water, we find that each of the cell-like spots is the home of an elegant little organism which may be seen to protrude through the mouth of its cell a delicate little crown of tentacles. Each colony of these animals consists of a common stock, bearing numerous little cells, and each cell contains its delicately organised inhabitant. Some of the little creatures become modified into bird's-beak-like graspers with two horny jaws, for the protection of the colony (fig. 45, B); others become altered into globular pouches for the reception of the eggs after their extrusion. Each of the dwellers in these little cells consists of a saccular body containing a looped digestive canal, in the bend of which a nerve ganglion is placed, and it is provided with a crown of hollow tentacles guarding the mouth. Most of these moss-polyps are marine and have a circular protrusible basis, supporting the tentacles; some few are inhabitants of fresh water, and these have the tentacles on a horse-shoe-shaped basis; these also have a little valve to shut the mouth, which is present in only two of the marine forms. Each of the little constituent animals of one of these colonies has its own digestive canal, its own nervous system,

FIG. 45.

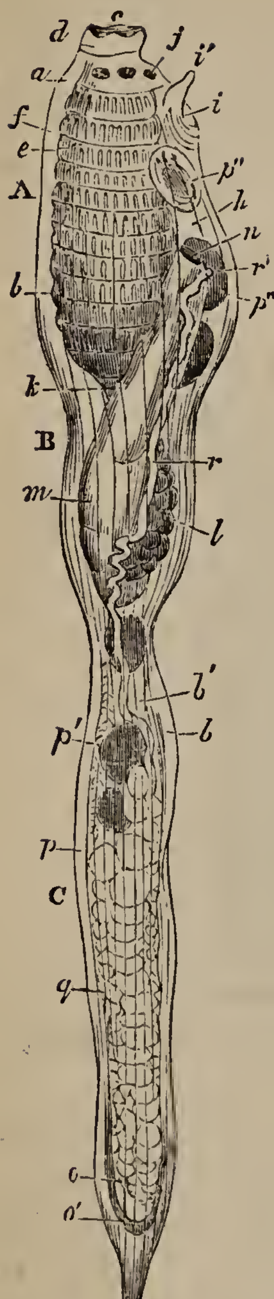


A. Natural size of *Acamarchis avicularia*, one of the Moss Polyps; B. Magnified view of one Polype, showing its 'bird's head.'

and its own egg-producing apparatus, and these are essentially like the corresponding organs in worms.

CLASS X. **Tunicata.**—These also are marine soft-bodied animals, met with in abundance attached to shells and stones among the tangles on our sea shores. They are often called sea-squirts, on account of their ejecting little jets of water from their terminal openings when irritated. They appear as irregular or oval

Fig. 46.



Amouroucium, a tunicated worm.
A, Pharynx, or respiratory portion of the body; B, stomach; C, egg-producing organ.

masses of semi-transparent, often gristly material, and of a whitish, pink, or brownish colour. They vary in length from 1 to 6 inches.

In each tunicary there are two apertures on the surface; one of these (*c*, fig. 46) opens into a large chamber whose wall (*e*) is a vascular membrane, and at the bottom of which is the mouth (*k*). The digestive canal ends at the bottom of a second chamber (*p''*), of which the lower or hinder opening is the outlet. Between these two chambers, which thus lie over the digestive canal, there is a partition wall which is pierced by many small holes whereby the water which enters into one can pass into the other, thus bathing the surface of the lining membrane, and enabling the blood contained in the spaces in its texture to become aerated. The first chamber (fig. 46) is called the branchial chamber, the second is called the atrial.

Between the opening of the branchial chamber and the atrial orifice there is a nerve ganglion sending a fine loop of branches around the mouth. The heart lies at the lowest part of the body and from it the vessels pass into the wall of the branchial chamber. In the action of this heart a curious appearance is observed; the blood is driven by this vessel first from one end to the other, for a second the action stops, then it is resumed in the opposite direction, again another cessation, and another reversal, &c.

The 'tunic,' or outer wall (*f*) contains a starch-like compound which is interesting as it is almost the only instance of the occurrence of a starch-like compound in the Animal Kingdom.

Young tunicates as they emerge from the egg appear as small, tailed larvæ, with bodies consisting of two cavities. The axis of the tail consists of a cartilaginous or gristly rod; in one cavity of the body the nerve ganglion is developed, in the other space the viscera are formed. Thus they foreshadow the structure of vertebrate animals.

Tunicaries are sometimes solitary, but many species are found united into social assemblages, and this union may go as far as the perfect union of the blood-vessel systems, a single vascular apparatus supplying the whole colony. In one group, the Salpæ, there is an alternation of generations, solitary and colonial forms succeeding each other in a cycle.

Many of the tunicates are phosphorescent, Pyrosoma, a compound form inhabiting the Atlantic ocean, being the most vividly luminous animal met with in the seas.

Summary.—The chief types of worms may be tabulated thus:

1. Unjointed, ciliated, non-parasitic forms without ciliated head-lobes = Class Turbellaria.

2. Unjointed or obscurely segmented minute forms, with ciliated head-lobes = Class Rotatoria.
3. Parasitic, flat-bodied forms, with no body cavity, and provided with suckers = Class Cotylidea.
4. Parasitic forms with no suckers nor digestive canal, and with a hook-bearing proboscis = Class Acanthocephala.
5. Cylindrical, unjointed, non-ciliated forms, with digestive canal and body cavity, mostly parasitic = Class Nematelmia.
6. Segmented forms with a proboscis, and convoluted intestine, non-parasitic = Class Gephyrea.
7. Segmented, bristle-clad worms with no suckers, moderate intestine, non-parasitic = Class Chætopoda.
8. Segmented, unbristled, sucker-armed, external parasites = Class Hirudinea.
9. Sessile, one-jointed, colony-building worms living in cells and with a crown of protrusible tentacles = Class Bryozoa.
10. Sessile or free, one-jointed worms, with one nerve ganglion but no protrusible crown of tentacles = Class Tunicata.

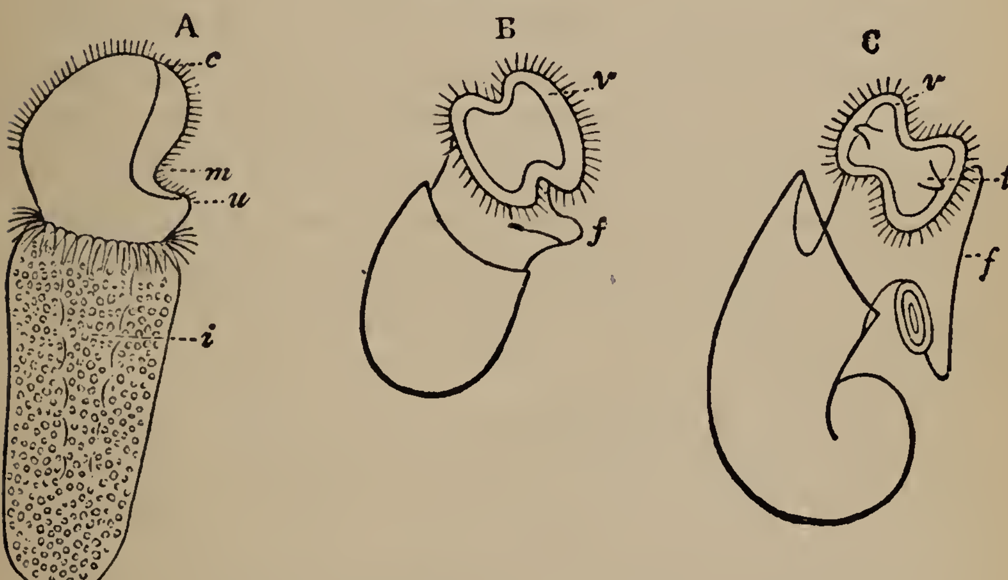
CHAPTER XV.

SUB-KINGDOM VI. MOLLUSCA, SOFT-BODIED ANIMALS.

THIS division includes all such forms as oysters, whelks, snails, and cuttlefishes. Most of these are aquatic and in none is there an inner skeleton (except some small gristly organs in cuttlefishes) nor are there any limbs, properly so called, in the whole group The outer tunic of the body is generally thick and extended to form a leathery envelope or mantle, the outer surface of which secretes a shell of carbonate of lime for the protection of the animal.

The earliest condition of existence of a mollusc, after it has left the egg-stage, is as a small ciliated, worm-like body having at its head an expanded lobe, richly clothed with cilia and resembling the trochal

FIG. 47.

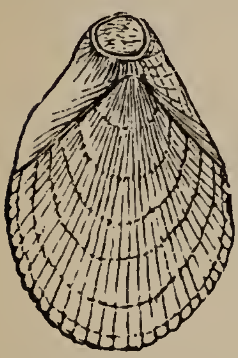


Larval forms of Worms and Molluscs. A, Larva of a Gephyrean Worm; B, C, Larvae of Molluscs, showing the ciliated velum *v*, and the rudimental foot, *f*.

discs of a rotifer, or the tentacle-bearing basis of the moss-polyps (fig. 47, B). This process is lost in the adult in general, but is interesting as one of the many evidences of the relationship between worms and molluscs.

The shells secreted by molluscs consist of one, two, or several valves, or pieces, and are very various in shape, and often brightly coloured. All molluscs have a digestive canal, and sometimes a complex arrangement of teeth. They have likewise a nervous system consisting of a ring around the fore-end of the digestive canal, on which are formed ganglia over and under the tube; besides this there are often other nerve masses and organs of sense. There is a heart which propels the blood, but there are few or no blood-vessels, the circulation being chiefly carried on in the interspaces of the tissues. There is rarely much of the body-cavity to be found free, with the exception of a small space around the heart, which is called the pericardium, and from this two short tubes pass out representing the segmental organs of worms. Four classes are included in this sub-kingdom.

FIG. 48.



Lamp-shell or Terebratula, one of the Brachiopods, dorsal surface.

CLASS I. **Brachiopoda.**—Of this class comparatively few representatives are now living, and these in few places, usually at considerable depths in the sea; but at an earlier period of the world's history they were very abundant. They possess shells of two valves, one of which is large, placed ventrally or downwards, and having a beak pierced with a hole, through which a foot-stalk projects whereby the animal is anchored. The other valve is smaller and placed dorsally; it bears on its inner surface a delicate shelly loop for the attachment of the peculiar arms from which the name of the class is derived. The valves are joined, either by horny matter as in the duck-bill shells (*Lingula*) of Australia, or by tooth-like hinges, as in the lamp-shells (*Terebratula*), and there are several muscles for opening and others for closing the valves. The mantle in Brachiopoda is full of blood-spaces, which are the only breathing organs in these animals, and there is said to be a heart lying on the stomach for driving on the blood. Some anatomists dispute the presence of a heart, and claim that the blood is impelled through the body by ciliary action alone.

The larvæ of Brachiopoda are freely locomotive and possess eyes and ear-sacs, but the eyes disappear in the fixed adult in which the ciliated head lobe of the embryo becomes converted into the basis of the arms. These arms are long and hollow, usually spiral and clothed with tentacles, and their to-and-fro motions cause currents which bring the food within the reach of the mouth of the stationary animals.

CLASS II. **Lamellibranchiata.**—More familiar to us are the representatives of the second great group of molluscs, oysters, mussels, cockles, &c. These are easily recognised by their bivalve shells, and by the two-lobed mantle under whose folds are the gills or breathing organs arranged in layers or lamellæ.

The freshwater mussel, or the large Mya or clam, easily found along our coasts buried in the sand, out of which the tips of their long siphonal tubes project, are good examples. The shell of one of these exhibits to us a beak or point on each valve, and is marked by numerous lines parallel to its margin; the inner surface also differs in texture from the outer, being whiter and often exhibiting a mother-of-pearl lustre. The cause of the difference in appearance is seen on making a microscopic section through a shell, as the outer surface is composed of long, nearly vertical, prisms, while the inner surface consists of fine layers whose edges overlap each other. These edges

Fig. 49.

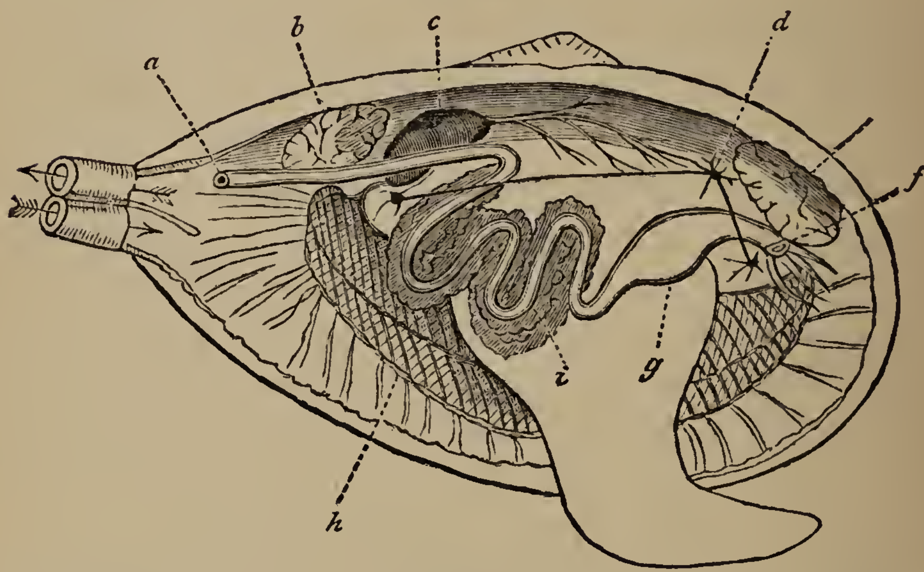
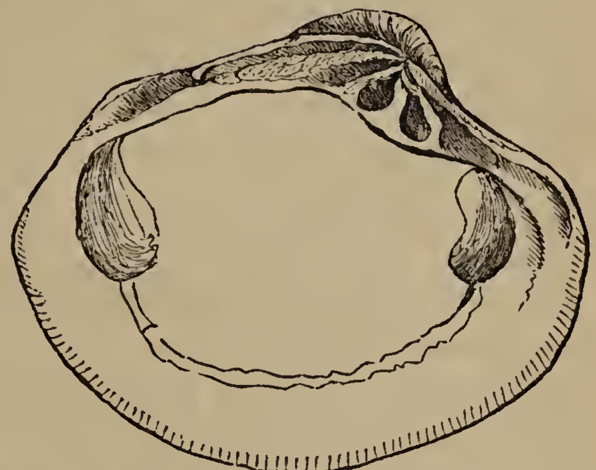


Diagram of the anatomy of a Lamellibranch, or Bivalve Mollusc. *g*, stomach; *i* intestine surrounded by the liver, the two tubes on the left marked by arrows are the canals of the siphon. *a*, the anus; *b*, hinder adductor muscle; *c*, heart; *d*, nerve ganglia; *e*, fore adductor muscle *f*, mouth; *h*, gills.

are often finely waved, and so decompose the rays of light which fall on them, thus producing the iridescent appearance seen in so many shells. The nacreous or mother-of-pearl layers are secreted by the surface of the mantle, while the prismatic material is formed by the margin of that structure. Thus the shell is constantly increasing in size by the formation of new prismatic matter, the lines of growth being the concentric curves before noticed. The edge of the mantle is sometimes fringed, and the irregularities secrete corresponding processes on the shell in the forms of ridges, spines, &c. On the inside of the shell a line of demarcation shows where the nacre-secreting surface ends, and the prism-secreting portion begins, this is called the pallial line (fig. 50).

Fig. 50.



Shell of Galathea, showing the hinge, mantle line and the two adductor scars.

Hinge.—The two valves of the shell in Lamellibranchs are usually similar to each other; they are disposed laterally, one on the right and one on the left, and are united by a hinge of interlocking teeth at the dorsal margin. A highly elastic ligament unites the valves outside to the hinge, and is so arranged that it keeps the valves slightly open. On the inside of a bivalve shell there are to be seen one or two oblong scars in each valve to which are attached muscles running from valve to valve for the purpose of closing the shell, and hence called adductor muscles.

Soft Parts of Bivalves.—The lobes of the mantle are usually more or less united along the under border, and are often prolonged backwards into a long tube or siphon which projects at the hinder end of the body; when this tube exists, the pallial line is indented posteriorly into a sinuosity called the pallial sinus.

Many bivalves are fixed in the adult state; in the oyster, scallop, &c., the animal lies on one side, the under shell adhering to the surface on which it rests. The common mussel is fixed by means of an anchorage of strong fibres (called *byssus*) secreted by a gland on its foot. Under each lobe of the mantle lie the lamellar gills, between which is a fleshy protrusion, the foot or organ of locomotion. At the front is the mouth (fig. 49, *f*) from which the digestive tube is continued backward, to open above the posterior adductor muscle as seen in the sketch. The last portion of this digestive tube passes right through the cavity of the heart. The siphon, when it exists, is a double tube, consisting of an upper and a lower passage; through the latter the food and water for breathing purposes enter into the mantle cavity and bathe the gills; through the upper tube the excreted matter and the water returning from the gills are ejected. There is a nerve ganglion above and below the digestive canal at the base of the little lobes around the mouth ('labial tentacles,' seen in fig. 49 as lancet-like processes), and another exists in the foot below the digestive tube; a fourth is placed posteriorly beneath the hinder adductor muscle. These animals have no recognisable head, but some of them have eyes on the siphon, as in the razor-shell (Solen); others have eyes along the edge of the mantle lobes, as in the common scallop. The larvæ of all bivalves have eyes, but these are lost in the course of development, and when such organs appear in the adult they are of secondary formation.

Bivalves are wonderfully prolific; the freshwater mussel has been estimated to lay between two and three millions of eggs in a season, and the oyster, it is computed, will produce over half a million of eggs in a year.

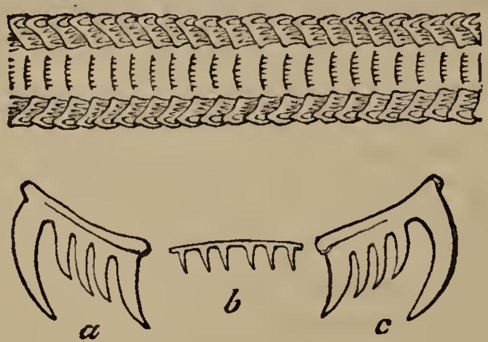
Classification.—Bivalves are subdivided according to the number of the adductors, according to the equality or inequality of the two adductors when both are present and (when there are two equal adductors) according to the presence or absence of a pallial sinus (page 82). The oyster is an example of the group which has one adductor. The mussel, of the group with two unequal adductors. The freshwater mussel and the cockle are examples of the group with two equal adductors and no pallial sinus, and the gapers, stone borers, and razor-shells, belong to the section with equal adductors and a pallial sinus.

CHAPTER XVI.

HEAD-BEARING MOLLUSCS.

Class III. **Cephalophora.**—The snail, whelk and limpet are examples of a class of molluscs, each of which has a distinct head furnished with sensory organs, such as eyes, ear-sacs and feelers. These possess a mouth armed with teeth, arranged on a ribbon placed at the bottom of the mouth cavity; this band can be drawn backwards and forwards by a set of muscles, and thus can act like a chain saw. This band can be easily found in the common limpet or whelk, where it exceeds an inch in length.

FIG. 51.



Tooth ribbon or radula of the Whelk or Buccinum; *a, c,* lateral teeth of one row; *b,* medial teeth.

In all but the little elephant's tooth shell, the mantle lobes do not entirely include the body, and the shell consists only of one valve. It varies in shape, sometimes being conical as in the limpet, but usually it is spirally coiled, the curvature being due to the mode of growth, as one side of the animal grows rapidly, the other slowly, or not at all; hence the body becomes coiled towards the aborted side, and the gills and other organs are generally developed only on one side. In most coiled shells, curvature is towards the left side, throwing the mouth round to the right side; in a few rare cases, or as an anomaly of growth, the coil may be reversed, winding to the right, and with the mouth at the left side. The bodies of these molluscs usually project, but they can be retracted into their shells. Progression takes place with a gliding motion, produced by the undulatory movement of the under side of the foot, as may be seen by placing a snail on the outside of a window pane, and watching it from within. The foot sometimes bears at its hinder part a little shelly lid which, when the animal is retracted into the shell, acts as a door to shut up the cavity;

this lid (or *operculum*) can be seen in the whelk and it is in shape similar to the outline of a section across the opening of the last whorl of the shell.

The mouths of some shells are channeled at their front end (the end farthest from the coiled part), and

FIG. 52.

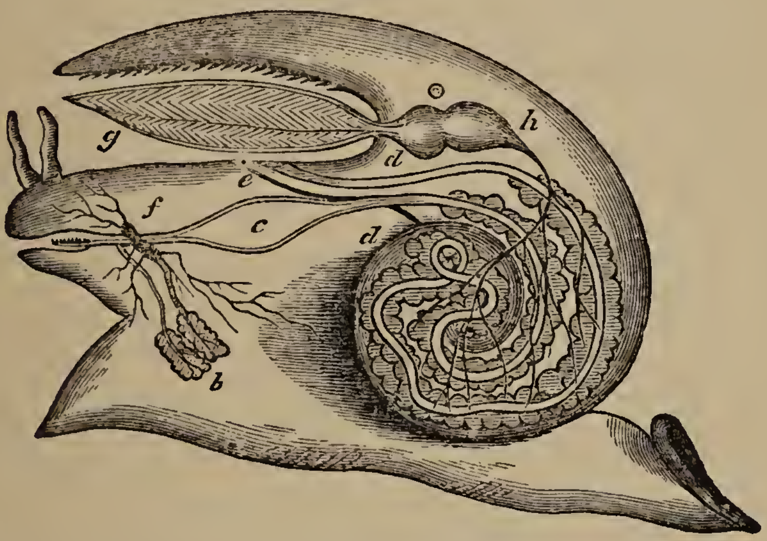


Diagram of the Anatomy of a Whelk, the shell being removed. *c*, stomach; *e*, end of the intestine; *g*, gills; *d*, auricle; *h*, ventricle of the heart; *f*, nerve-ganglia of the mouth; *b*, salivary gland.

sometimes at their posterior end; these channels are for siphon-like tubes, and as a general rule such molluscs as possess these siphons are carnivorous, while those with unchanneled or entire edges are herbivorous.

Some univalves, like the common snail and slug, live on dry land; in such forms gills would be useless, and hence they are absent, and a part of the mantle cavity is set apart for air-breathing, and the lining of this region is full of dilated blood-vessels. The mouth of this air-chamber is small, and can be seen opening and closing periodically in the common black slug on the left side of the body, under the edge of the little saddle-like rudimental shell, which in this mollusc is enclosed in the mantle.

The heads of univalve molluscs bear several organs of sense, tentacles, eyes and ear sacs, the tentacles are long soft feelers, the 'horns' of the snail, which can be retracted by being involuted, or turned out-side in by muscles. In the common snail the eyes are placed on the extremities of the upper or longest pair of horns, and can be seen as bright black spots. In other molluscs the eyes are either stalked or placed at the bases of the tentacles. The organs of hearing are small sacs placed near the foot, filled with fluid and containing small concretions. Most univalve molluscs lay their eggs inside little cases often to be met with under stones on the sea-shore. The little ciliated larva has a shell even at its earliest stage, and in some molluscs this shell is lost in development; in others it is retained and can be seen at the tip of the adult shell as the 'nucleus.'

Classification.—The head-bearing molluscs are very numerous, and are divided into several sub-classes. The first of these includes the little elephant's-tooth shells, or Dentalium. This animal has no heart, and is completely enclosed in its mantle, which in the embryo forms at first a minute two-valved shell. Eventually, however, this shell becomes tubular, open at both ends. The second sub-class consists of small molluscs found swimming in the ocean, by means of two large wing-like processes on the upper part of their foot, and hence are named

Pteropoda. The third sub-class includes all the remaining forms, a few of which are free, swimming with the foot flattened into a screw-propeller. Most of them crawl on the under surface of their body, and hence are called *Gasteropoda.* Among these, a large number are branchiate, or gill-breathing; these make up one order; the others are pulmonate or air-breathing, and make up a second order. The branchiate forms have the gills either in front of the heart or else behind the heart, as in the great group of shell-less naked-gilled molluscs like the Doris or Æolis, so common on the shore. Some of the former sub-order have shells of eight valves, like the common Chiton; others have the gills all round the body, under the mantle, and equal on both sides, as in the limpets, or they may be unsymmetrical as in the ear-shells, cones, shoulder-of-mutton shells, etc.

Snails.—The air-breathing order are the land shells or snails; they have their breathing chamber placed behind the heart, and the larva has in general a very rudimental ciliary lobe. A curious difference has been noted between the gill-bearing and lung-bearing molluscs, namely, that the intestinal tube is bent towards the hæmal side of the body, that is, towards the heart, in the former, while it is turned towards the nerve-ganglion in the latter.

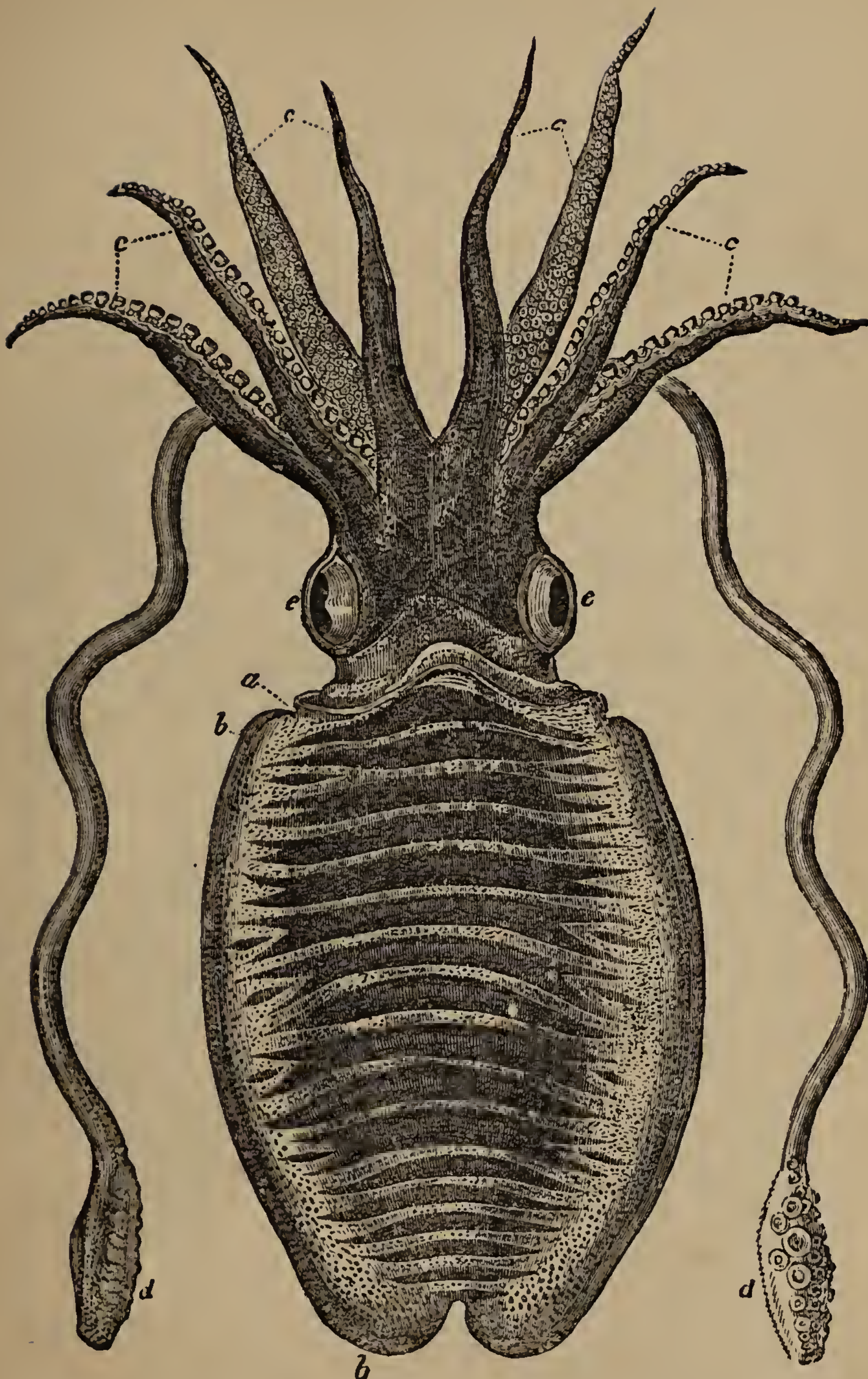
CHAPTER XVII.

CUTTLEFISHES.

CLASS IV. **Cephalopoda.**—The highest class of molluscs is that which consists of Nautili, Cuttlefishes and Squids. These are all highly organised marine animals with a central mouth, around which there are processes of the foot, disposed in the form of a circlet of arms or tentacles; each of these arms is provided with one or more rows of large suckers, and thus they form a powerful grasping organ, which they use in taking the prey whereupon they feed.

Shells.—Very few of these are enveloped in shells, and most of them progress, when creeping, with the head down, and with the large mantle cavity at the hinder side. There are three kinds of shells found clothing, or contained in, some animals of this class. These are 1st. The chambered shell, such as that of the pearly nautilus (fig. 54, p. 92), a coiled spiral divided by numerous partitions into successive chambers (*b*), each of which, however, communicates with the neighbouring chambers by means of a tube or siphuncle (*c*). 2. The enclosed shell, a horny or calcareous plate or oval mass, embedded in the integument, or lying in a closed cavity along the front wall of the animal's body; such a shell is found in the cuttlefish and squid. 3. In one species there is a singular shell secreted by two of the arms which lie beside the mouth, and which are flattened organs, and the shell so secreted is a slightly spiral

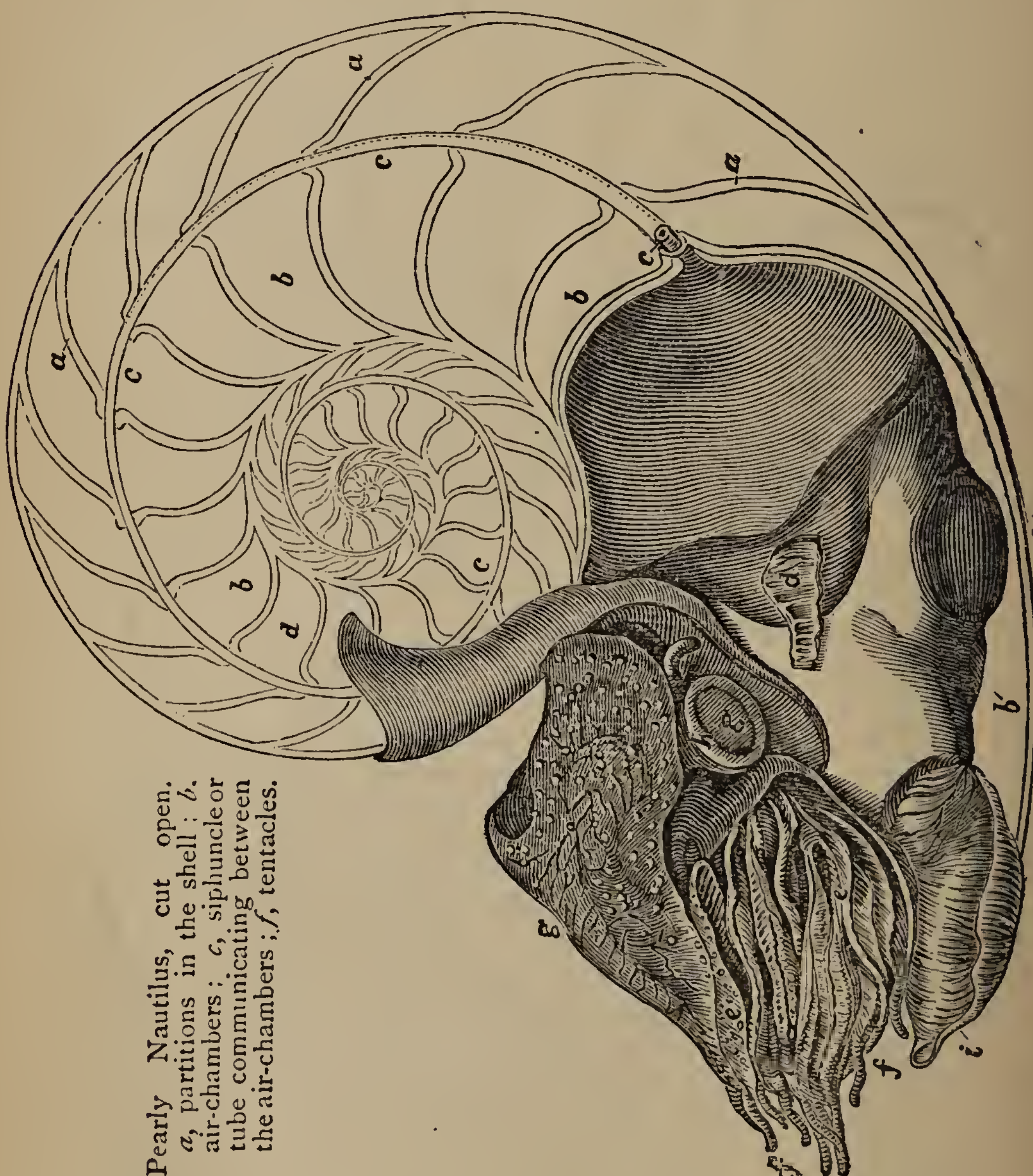
FIG. 53.



Cuttlefish or Sepia. *c*, Arms bearing the suckers; *d*, long tentacle-like arms; *a*, mantle; *b*, lateral fins; *e*, eyes.

rapidly expanding shell of a delicate paper-like texture to which the name 'paper nautilus' or Argonaut has

FIG. 54.



Pearly Nautilus, cut open. *a*, partitions in the shell; *b*, air-chambers; *c*, siphuncle or tube communicating between the air-chambers; *f*, tentacles.

been given. Other species, like the Octopus or sea-spider, have no shell either internal or external.

Anatomy.—On account of the fore-shortening of the body the mouth is brought into the middle of the foot in the adult, and hence the name 'head-footed' (*Cephalopoda*) given to this class. The lobes into which the foot is divided are usually eight or ten in number and are long tapering muscular processes which in the common species in our own seas vary from a few inches to two feet in length, but in one rare form they attain very much greater size. During the year 1873, a specimen was captured on the Newfoundland coast, with arms forty-two feet long.

The mouth is furnished with a strong beak, like that of a parrot, with two formidable horny jaws. By reason of the numerous suckers on the arms (a common octopus possessing about 60 on each arm), which seize hold of their prey with a cupping-glass-like tenacity, these cuttlefishes are among the most terrible of marine monsters, and those of large size would probably prove to be more than a match even for man himself.

Each of the sucking disks is singularly perfect in its structure. There is a muscular adhesive disk of a circular shape, around whose edge is a hard crown of horny consistence, and in the centre there is a muscular retractile piston, whose contraction produces a vacuum, and thus causes a close adhesion of the sucker.

There is a large mantle cavity with a strong muscular wall. When the animal is swimming it moves with its arms directed backwards and the upper or pointed end of the body forwards; in this position the opening of the mantle cavity or funnel is directed backwards, and the propulsive force which drives the body forwards is the sudden and often repeated contraction of the wall of this cavity, which by driving a column of water in the opposite direction with great force, propels the creature by rhythmical jerks, and at a rapid rate.

On slitting open the mantle two large gills are seen, one on each side, above and between which is the heart-ventricle. The blood enters the gills by large veins which form dilatations at the base of these breathing organs, then after being aerated, it is collected in two cavities called *systemic auricles*, from whence it passes into the muscular ventricle which drives it through the arteries into the lacunæ (or tissue interspaces of the body).

Along the hinder edge of the long digestive canal there is a slender tube, whose opening is also at or near the mouth of the funnel, and whose upper end expands into a large spongy-walled sac lying close beside the liver. This sac secretes a brown or black inky material which is poured out in enormous quantities when the animal is pursued, and which by rendering the water opaque covers the flight of the cuttlefish.

At the mouth of the mantle-cavity but not actually connected with it there is a funnel, which when the margin of the mantle contracts forms a narrow tubular outlet for the fluid of the cavity.

Cuttlefishes possess a brain, made up of large confluent ganglia around the pharynx, and over this there is a cartilaginous cover, interesting as being one of the first signs of an internal skeleton, like that of vertebrates in the animal kingdom. There is also a large and complex eye, more like that of a vertebrate animal than is the eye of any other group of invertebrates.

Cephalopods were abundant in former ages, but there are now about 230 species living; of these the Nautili possess a chambered shell, four gills, and many tentacles, while all others have only two gills, and eight or ten sucker-bearing arms.

Recapitulation.—Having thus very briefly reviewed the sub-kingdom Mollusca, we may, by way of recapitulation, place in a tabular form the distinctive characters of the group and its divisions. They are all soft-bodied, never distinctly divided into segments nor provided with jointed limbs; enveloped more or less in a dermal mantle, which often secretes a shell, and their larval stage is usually ciliated, worm-like.

The divisions are:

A. Having no distinct head, bivalve shells with the valves dorsal and ventral; no separate gills = Class I. Brachiopoda.

B. Having no distinct head, bivalve shells with the valves right and left, gills lamellar = Class II. Lamellibranchiata or Acephala.

C. Having a distinct head, univalve shells (at some period of existence) = Class III. Cephalophora.

a. Entirely enclosed in a mantle, secreting a tubular shell = Sub-class I. Scaphopoda (Dentalium).

b. Not entirely enclosed in a mantle, swimming by finlike processes on the upper side of the foot = Sub-class II. Pteropoda.

c. Creeping by the foot or swimming, but not by finlike processes = Sub-class III. Gasteropoda.

d. Having the foot around the head, and modified either into tentacles or sucker-bearing arms = Class IV. Cephalopoda.

CHAPTER XVIII.

SUB-KINGDOM VII. ARTHROPODA (JOINTED ANIMALS).

General Characters.—This sub-kingdom includes those animals whose bodies are furnished with an external hard protective layer, and which bear jointed limbs appended to each segment of the body (fig. 55). The armour-plating of the body is known by the name *exoskeleton*, to distinguish it from the bones, which form the axis of support for vertebrate animals, to which the name *endoskeleton* is given. The exo-skeleton consists of *chitin*, a horny substance, which is capable of resisting all reagents except the most powerful corrosives. This layer is usually coloured, laminated, and to the microscope shows very little structure except the numerous fine canals which pierce it from within, to which the name *pore-canals* is given.

Fig. 55.

Sandhopper, or Talitrus.

The body of an arthropod consists of a chain of segments, all built on a common pattern, and each one strengthened by the possession of a ring of exoskeleton consisting of two parts, a dorsal, and a ventral half arch. The limbs are articulated on each side, between the half arches, each segment possessing one pair. These generally remain distinct, even when the segments, as often happens, fuse together, so that the number of constituent segments can be very often detected from the limbs, even when the body rings are united into a continuous shield.

The bodies of arthropods are bilaterally symmetrical. They are also remarkable for the absence of cilia at all periods of life.

Each limb consists of several joints, each having an external chitinous exoskeleton, containing the muscles which move it. In the simplest arthropods, the limb consists of a basal segment bearing two appendages, an outer and an inner. In the higher forms the limbs are divided into five, seven, or more joints. These limbs are used for various purposes, becoming modified into feelers, water-bailers, jaws, swimmers, pincers, or walking feet.

All arthropods have a circulatory system and most of them possess a heart which is a dorsal tube, divided by valves into successive chambers, but there are rarely fine blood vessels. There is a distinct respiratory system, and a complex digestive canal, except in parasitic forms, and they have all a symmetrical nervous system, consisting of two ganglia, one above, the other below the throat, followed by a chain of ganglia in the ventral portion of the body. They are divided into four great classes, 1. *Crustacea*, including all those that breathe by gills, as crabs, lobsters, &c.;

2. *Arachnoidea*, spiders, mites, and scorpions; 3. *Myriopoda*, centipedes, &c., 4. *Insecta.*

Many arthropods are parasitic, and these are at first not unlike allied non-parasitic species, but shortly after hatching they retrogress, such parts as are not necessary disappear and hence the adult parasites are in their organisation much simpler even than they themselves were in their embryonic states; but as has been already noticed, the egg-producing organs are much increased in development.

From two to six of the foremost segments of the body in arthropods become united to make up a head, which carries sentient organs, such as the eyes, ears, and antennæ or feelers, with the mouth. In the head likewise is the large supraœsophageal nerve-ganglion or brain, which sometimes is large and complex, as in ants.

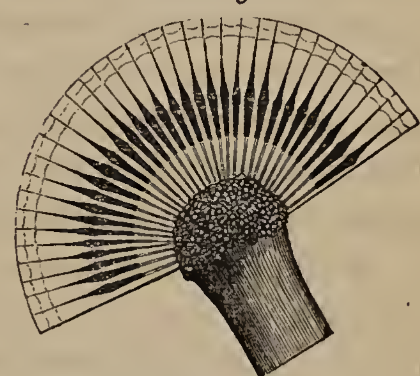
CHAPTER XIX.

CRABS AND LOBSTERS.

CLASS I. **Crustacea.**—The animals of this class are all water-breathers, either provided with gills, or else with a thin integument through which the blood becomes directly aerated. The structure of a crustacean can be easily understood by examining a lobster or freshwater crayfish. In either of these we notice that the body is divided into two regions, an anterior, covered by a dorsal shield of two pieces, and a posterior, consisting of a series of rings, ending in the fan-like tail. In the body of the lobster we notice three openings,—the mouth, the terminal opening of the digestive canal in the middle line of the last joint of the tail on the under surface, and the opening of the egg-producing organs at the base of the third pair of walking limbs. Through this last the eggs are extruded, and are carried in clusters under and around the bases of the hind series of feet.

In the large anterior mass of the body, sheltered by the dorsal shield, there are fourteen segments united, comprising the head, thorax, and abdomen. The head segments bear their six pairs of appended limbs, the first pair of which are modified into stalks for the eyes, which are remarkable organs, each consisting of a large number of rods of a crystalline appearance, each placed at the end of a nerve fibril or thread, and surrounded by a mass of pigment. The numerous united fibrils of the optic nerve pass in the centre of the stalk, and each fibril ends in its crystal rod, the mass of rods being arranged in a cluster, slightly divergent so as to exhibit a rounded outer surface, over which the chitinous skin extends as a fine, perfectly transparent covering.

Fig. 56.



Vertical section through the eye of an Insect, showing the stalk or optic nerve, the white radiating lines or secondary optic nerves and the crystal cones.

The second pair of limbs are feelers called the antennules or lesser antennæ, consisting of three basal joints, terminated by a pair of slender processes each made up of many little rings; these are followed by the third pair of limbs, or the large antennæ, consisting of five basal joints succeeded by a long feeler. The bases of the fourth pair of limbs are modified into biting-jaws or *mandibles*, and they bear an internal appendage named the mandibular palp. The fifth and sixth pairs of limbs are also jaws, and are called maxillæ; they also bear rudimental appendages. The three segments that follow the head segments, and are united thereto, make up the thorax, and their limbs are also in the lobster modified into organs of mastication, and hence are known by the name of foot-jaws; each of these except the first bears outer and inner appendages, but the third pair is of very little use as a chewing organ, but bears a gill as does also its anterior neighbour, the second pair of foot jaws.

Following the limbs of the cephalo-thorax, for so the united head and thorax is often called, we come to five pairs of walking legs, each pair being the limbs borne by a segment of the abdomen. These five abdominal segments are also in the lobster covered over dorsally by the dorsal shell, but on the under or ventral surface, their separateness can be very well recognised. The first pair of limbs consist of the pincers or *chelæ*. These formidable organs in the lobster are made up of seven joints, the last but one of these is very large, and its outer angle is prolonged into a finger-like process capable of being opposed to the last joint, thus making a grasping organ of great power. In the lobster the two pincers are not quite symmetrical; one is armed along the edges of the blades of the pincers with rough tubercles, the other with small serratures; the former claw is probably used as an anchoring apparatus, the latter for seizing articles of food.

The two succeeding pairs of abdominal limbs are also pincer-like at the extremity; the two following are simply pointed, but still exhibit seven joints. All the abdominal limbs, except the last, carry gills appended to the basal joint, and placed under cover of the dorsal shell.

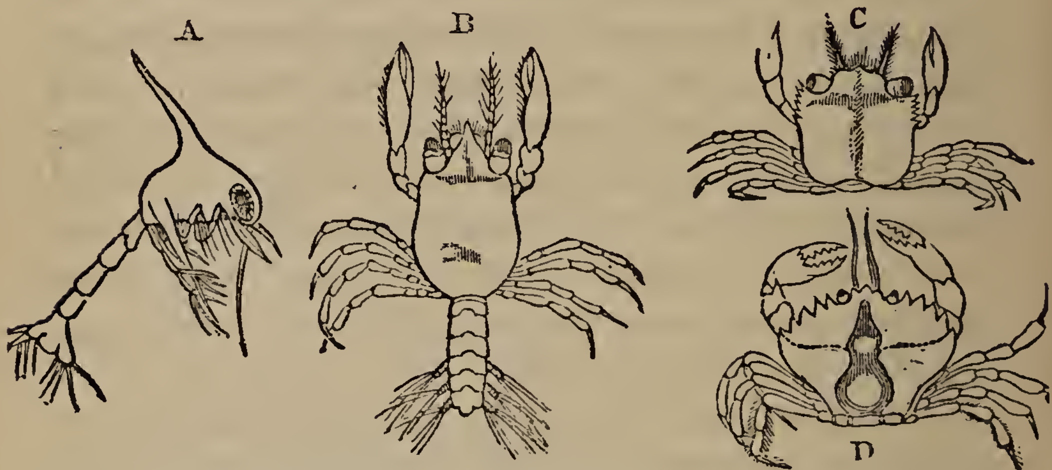
The six movable rings which form the 'tail' of the lobster, bear laterally limbs adapted for swimming, each made up of a basal part, and two flattened appendages external and internal; the last of these segments not only carries the widely expanded swimmer or tail fins, but bears at its hinder extremity also a single median flap or 'telson,' sometimes regarded as a separate segment. These movable rings make up the post-abdomen.

The ear in the lobster is a sac at the base of the antennule; the gills lie under the hinder and lateral parts of the dorsal shield. The stomach is a gizzard-like cavity with calcareous masses lining its walls, followed by a narrow soft-walled digestive stomach and intestine, below which lies the nerve-cord, and above it is the heart.

The crab differs from the lobster not only in shape but in the comparative immobility and small size of its abdomen, which is turned in and sunk into a groove. While the young lobster only differs from the adult in the possession of small outer appendages on the walking limbs, and the smaller size of the tail, the crab emerges from the egg in a form utterly unlike the adult, as a little swimming creature with a dorsal shield armed with a strong median spine (fig. 57, A) and followed by a jointed abdomen which bears no appended limbs.

A closely allied animal common on our shores is the hermit crab, which protects its soft, almost limbless abdomen by inserting it into the deserted shell of a whelk, or other univalve mollusc. In these

FIG. 57.



Stages in the development of the common Shore Crab (*Carcinus mænas*). A, First or zoea stage; B, early stage with tail; C, D, advanced stages of growth.

the pincers are usually unequal, so that on the animal being molested, one can be retracted while the larger one blocks up the passage. The soft abdomen acts as a sucker, whereby the hermit crab retains its hold on its habitation.

There are many varieties of form among crustacea, and those above described are among the most highly organised, all having stalked eyes and ten walking feet. The mantis shrimps have their thoracic limbs fitted for walking, as well as the abdominal legs, so that instead of ten, there are fourteen or sixteen legs.

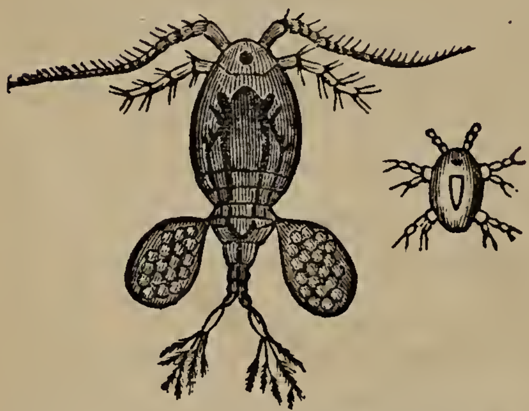
All these forms make up a sub-class of crustacea named *Podophthalmia* on account of their stalked eyes.

The sand-hoppers (fig. 55), wood-lice, and freshwater shrimps, make up a second sub-class, characterised by possessing sessile eyes. These also have bodies made up of twenty segments, each of which, except those of the head and thorax, has its own independent chitinous ring, and the two hinder pairs of foot-jaws are used for locomotion. Some of these, like the sand-hoppers and freshwater shrimps, have the three hindmost pairs of abdominal feet arranged so that their joints bend forwards while all the other limbs bend with their joints concave backwards. These are called *Amphipoda*, to distinguish them from those like the wood-lice, and slaters, whose legs are all directed one way, which are called *Isopoda*.

The king crabs of the Mollucca Islands and of North America form the types of a third sub-class. They resemble the lobster in having the head, thorax, and abdomen covered by a great dorsal buckler, but differ in that there are six walking limbs around the mouth, whose bases are spiny, and compressed, acting as jaws. The eyes are not stalked, and there is a long bayonet-shaped tail, behind the abdomen, corresponding to the telson of the lobster. The segments of the abdomen are faintly marked in the adult king crab.

In the past ages of the world, larger allied forms existed abundantly; other allied fossil forms had three-lobed bodies, and hence are known as *Trilobites*, and they are only found in palæozoic rocks. In stagnant pools of fresh water little creatures called water fleas can be seen, by the aid of the microscope, actively darting about; these are representatives of a fourth sub-class. They are all minute at the present day. Certain forms bear gill processes appended to their feet, and hence are known as 'gill-footed' or Branchiopods. Many closely allied species have the dorsal wall extended in the form of an enveloping shell, just like the gill-covering laminæ in the lobster.

Fig. 58.

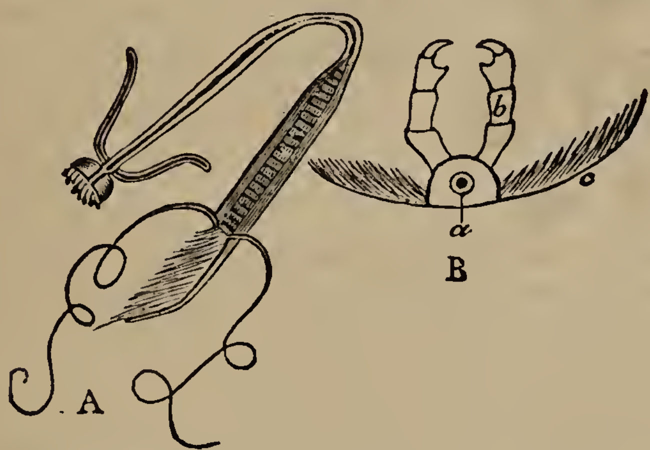


Cyclops quadricornis carrying its egg sacs. The small figure is the Nauplius or larva.

Those crustaceans which are parasitic are closely related to the water fleas, and undergo retrogression until they become reduced to little sacs with bristles for jaws, with sucker-like fore feet, and often with no trace of segmentation (fig. 59, A). Some live on the bodies of larger crustaceans such as lobsters, others on tunicates, but they are mostly found attached about the gills of fishes. The early stages of these are little, free, marine larvæ with developed jaws and a moderate post-abdomen (fig. 58). Many non-parasitic species remain for their whole life in a state like that of the larvæ of these parasites.

In all these lower crustaceans the earliest stage of existence after emission from the egg is in the form of a minute oval body with three pairs of limbs and one central eye. This is known as a Nauplius, and it assumes its adult form by the growth of new segments and new limbs. The nauplius stage of higher crustaceans is transitory, and sometimes is passed over before the embryo leaves the egg, and in crabs the form assumed by the newly hatched young is that of a small shield-covered body with two eyes and long jointed abdomen (fig. 57, A); this curious larva is called Zoëa, and by the shortening of its

Fig. 59.



Pennella, parasitic on the Sunfish. A, Entire animal, half real size; B, head.

tail and the vanishing of its dorsal spine, it becomes changed into its adult form.

All crustaceans undergo successive moultings or changings of shell, and during these changes lost parts become restored and the several changes in metamorphosis can be seen at these periods. Crustaceans part with their limbs easily under circumstances of fright or seizure; thus if a limb be taken hold of forcibly the animal will probably break it off between the first and second joints in its efforts after freedom. At the next moult, there appears a new limb budding on the soft uncovered body, and when the new shell forms and hardens, a small limb is seen in place of the lost one.

Some of the metamorphoses of crustaceans are strange; in none more so than in the barnacles and acorn-shells (figs. 4 and 5, pp. 9 and 10), the lowest subclass of the series. Acorn-shells or Balani, are the little limpet-like shells which encrust the rocks along all our coasts and which can be at once recognised by the opening at the top of the conical shell, which is closed by the lateral valve-like or beak-like plates. Barnacles are commonly found adhering to logs of wood or to ships' bottoms. These begin life as active nauplius-like larvæ, which every autumn are to be found swimming along our coasts. This larva at its early moults develops a lateral mantle-fold. At its fourth change in shell, the front of its head becomes fixed by the flattening of one of the joints of the antennæ and by the secretion poured out by a gland which, though placed in the body, has its duct opening in the altered joint of the antennæ. At the fifth moult the eyes and antennæ vanish, the head becomes fixed by a broad base of attachment, the mantle-like fold of integument surrounds the body and becomes calcified into a shell of many valves, within which the hinder parts of the body are enclosed together with their six pairs of limbs. These limbs remain free and capable of slight protusion, while the mouth with its mandibles lies at the bottom of the mantle cavity.

Some Balani select curious places of residence. Coronula lives on the skin of the whale; Anelasma often is adherent to fishes, and many others to corals. One closely allied group of degraded forms are parasites on the abdomen of crabs. To the sub-class comprising all these forms the name Cirripedia, or tentacle-footed, has been given.

Recapitulation.—We have thus seen that the seven classes of water-breathing, many-jointed forms which make up the class Crustacea are very dissimilar in details. They may be arranged in a tabular series as follows :—

A. Sessile Crustaceans, often pseudo-parasitic, usually enclosed in a many valved shell = Sub-class I. Cirripedia.

B. Free, with a cephalo-thorax and two pairs of thoracic limbs, none of the feet bearing gills = Sub-class II. Copepoda (fig. 58).

C. Free, with the body enclosed in a bivalve shell made of the extended dorsal integument = Sub-class III. Ostracoda.

D. Free, with no enclosing shell, feet gill-bearing, segments less or more than twenty = Sub-class IV. Branchiopoda.

E. Free, with a large cephalo-thorax, small walking limbs, six pair of which are arranged around the mouth = Sub-class V. Pœcilopoda. King Crabs.

F. Free, with a cephalo-thorax, stalked eyes and a body of twenty segments = Sub-class VI. Podophthalmia.

 A. Thoracic limbs masticatory, ten abdominal limbs alone fitted for walking = Order I. Decapoda.

  a. With a long abdomen : Lobsters = Sub-order I. Macrura.

  b. With a soft limbless abdomen : Hermit Crabs = Sub-order II. Anomura.

c. With a short up-turned abdomen: Crabs = Sub-order III. Brachyura.

B. Some thoracic limbs ambulatory, thus making twelve, fourteen, or sixteen pairs of walking limbs = Order II. Stomapoda.

G. Free, with a cephalo-thorax, twenty segments and sessile eyes = Sub-class I. Edriophthalmia.

CHAPTER XX.

SPIDERS AND MITES.

Class II. **Arachnoidea.**—These are terrestrial air-breathing creatures in which the segments that compose the head and thorax are united to form a single cephalo-thorax, but their articulated limbs are to some extent represented, and of these, four pairs are usually used in walking. There is an abdomen with a variable number of rings. Whenever eyes are present they are not compound bundles of crystal rods covered by a common *cornea*, as in crustaceans, but they consist of separate transparent cones surrounded with pigment and always few in number. There are never any antennæ developed as such, but the mandibles are always present, and, in scorpions, the maxillary palps form pincers or claws like those of a crab; such claws are called *cheliceræ*. The second pair of maxillary palps form the first pair of walking limbs, while the first and second pairs of thoracic limbs, as seen in the true insects, are developed as the second and third pairs of legs, and the third pair of thoracic limbs is absent; at the base of the abdomen is a curious pair of comb-like organs in the scorpion. The parts of each limb are like those in Crustacea; the body and its organs are however much shorter than in that class. The nervous system is concentrated, the digestive canal often has blind pouches appended to it. There is an abdominal heart in all, except in a few mites, and there is usually a series of breathing tubes. Organs of touch, smell and hearing seem to be deficient.

Many of these animals are parasites, either external, or internal; but except in these, there are few in which the young undergo much metamorphosis after hatching.

The outer surface is often hard and chitinous, but never calcified. The dorsal surface layer is seldom extended over any of the neighbouring segments or appendages, or when extended it is immovable.

Mites.—The three orders in the class consist of mites, spiders and scorpions. Of these the mites are the simplest and are exemplified by the cheese-mite, found in mouldy cheese, or the sugar-mite often met with in brown sugar. In these the abdomen is unsegmented, and usually indistinctly separate from the cephalo-thorax. The breathing organs are fine tubes named tracheæ, which open on the surface, and break up within the body into branches, which admit air into the tissues. The mouth in mites is often proboscis-like or armed with a spiny beak. Most of them are parasites either upon animals or plants. One curious group inhabits the body cavities of vertebrate animals, wherein their worm-like bodies may be mistaken for tape- or thorn-

FIG. 60.

Cheese-mite (*Acarus*).

headed-worms. They are however easily distinguished by their embryos bearing true jointed limbs, although these are lost in the adults.

One form has been found in the contents of the small fat glands on the human face, and another is the cause of the disgusting skin disease known as 'itch.' Other larger forms are the 'ticks' found so commonly on sheep, dogs, bats, camels, &c. Of non-parasitic forms, the little 'red-spider' so often seen on the sea-shore under stones between tide-marks, and the 'glass-' and 'garden-mites' found in damp moss and among vegetables are examples.

Spiders.—In spiders the cephalo-thorax is joined to the sac-like abdomen by a narrow stalk, and the latter portion never bears any limb-processes. The tracheæ, instead of being bundles of branching tubes, are condensed and flattened, and included in definite spaces, in which the compressed tubes look like the leaves of a book, the whole laminated organ on account of its being circumscribed and lung-like, is called a *tracheal-lung*, and the spiders are often called pulmonary arachnoids on account of their possessing these organs.

Fig. 61.

Scorpion.

Spiders have little clusters of simple eyes on their foreheads, bright small specks usually eight in number and generally arranged in two rows. The mandibles have at their inner side the duct of a poison-gland whose secretion they instil into the insects which constitute their prey. The stomach is like a hollow ring from which radiating blind pouches pass off, and the digestive tube is short.

Near the hinder end of the abdomen in spiders, there is a flattish 'spinning area' upon which open the glands which secrete the web. On this area there are usually three pairs of little wart-like spinnerets; and numerous small pores, from each of which a minute thread of web-material issues, open on the surface of each spinneret. Sometimes one pair of the little knobs consists of a palp-like process. In the common house-spider (*Tegenaria domestica*) there are 400 such holes on each wart, hence each thread of the web consists of several hundred strands; the material is at first fluid, but rapidly becomes hard and chitinoid. In commencing to spin, the spider applies the spinnerets to the surface of some fixed body, and then as it moves away, the material is drawn out. The hind feet press the several strands of the web-thread together, their comb-like claws appearing to be important instruments for this purpose.

In the web of the garden spider, whose geometrical nets are frequently seen on old fences and palings, there are three kinds of threads to be noticed. 1st. The marginal and stoutest radial threads. 2nd. The intermediate radial threads, both of which are uniform, though differing in size and in elasticity, wherein the secondary exceed the primary. 3rd. The concentric threads which are bedecked at regular intervals with little viscid globules.

Other spiders excavate cavities in the ground; these they line with a silky web, and over the mouth of them they make a trap-door lid of alternate layers of earth and web united together and hinged by a silken hinge. These trap-door spiders are found along the shores of the Mediterranean, in California and Jamaica. Some spin little cocoons or silken cases for their eggs, which they carry about with them, and in protecting which they exhibit great activity. The maxillary palps are never pincer-bearing or used for walking, although sometimes long.

Scorpions.—The scorpions and their allies are characterised by the possession of a long segmented abdomen, ending in a tail-like portion. The maxillary palps form pincers, like crabs' claws, and breathing takes place by pulmonary sacs like those of spiders. The last joint of the abdomen bears in scorpions a sharp spine at its end, perforated by the duct of a poison-gland, and thereby it inflicts painful wounds. A little creature named Chelifer, somewhat allied to scorpions, but with no tail nor sting, is often found in old books.

CHAPTER XXI.

CENTIPEDES. GALLYWORMS.

Class III. **Myriopoda.**—This comparatively small class includes the centipedes, whose long jointed bodies are to be seen rapidly crawling under old rotten sticks and stones and shunning the light. In this country they rarely exceed three inches in length, but in the tropics they reach from six to twelve inches or even more, and their bites are poisonous and severe. One

British form is phosphorescent, and another is described as capable of giving electric shocks. The body consists of many segments which, with the exception of the head and the last joint, are similar in appearance; the head bears the eyes, which are usually simple like those of spiders, and generally in two rows. Near these there are the sensitive, slender, thread-like antennæ, consisting rarely of seven, usually of fourteen joints or more. These animals are usually carnivorous and have a strong pair of mandibles, situated on each side of the mouth, and two pairs of maxillæ, either or both of which are sometimes united together in the middle line, forming a lower lip for the mouth; the anterior of these have jointed palps. The hindermost segment of the body has often a pair of long limbs directed backwards. There is a straight digestive canal with a number of tortuous glands appended to it, and a long tubular heart made up of a chain of chambers one in each segment separated from each other by valves.

FIG. 62.

Centipede (*Lithobius*).

On each side of the body open the mouths of the tracheæ or tubes for breathing; there may be one on each segment or one on every second joint. Each opening is the beginning of an air-tube, which on entering the body branches irregularly, the fine branches freely communicating with each other. To keep these tubes open there is a spirally coiled thread of *chitin* in their lining membrane, which like a spring prevents them from collapsing, and to keep the mouth from being choked there is usually a raised margin sometimes provided with little processes. One curious group has no tracheæ.

Many of these centipedes have minute pear-shaped glands placed along the sides, which secrete a brown irritating fluid, emitting a disagreeable odour.

There are more than twenty segments in the body (except in one little species), and each bears one or two pairs of legs, all with six or seven joints like those of a spider or crustacean; each limb terminates in one or two claws.

Subdivisions.—There are three orders of these animals, millepedes, centipedes, and pauropods. Millepedes possess two pairs of limbs on most of their segments, a condition due to the union of the true segments in pairs. They have also small antennæ of seven joints and tracheal openings in front of the articulation of each leg. They are found in this country in the rotten wood of decaying trees, and when disturbed roll themselves up into balls.

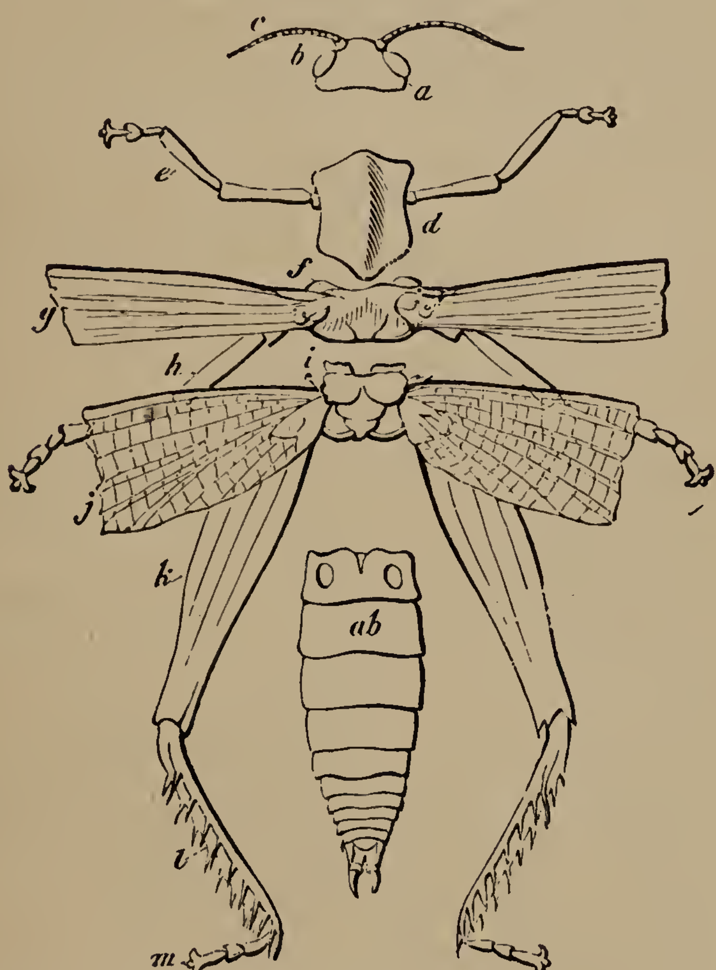
Centipedes are found under stones in damp outhouses, or in rotten palings. They have but one pair of limbs on each joint of the body, and never more than one pair of stigmata. The native forms are small, but the tropical Scolopendræ are of very large size and their bites are exceedingly severe. The one species of Pauropus is a minute white creature found in decaying leaves, with no tracheæ, ten segments and five-jointed antennæ.

CHAPTER XXII.

INSECTS.

CLASS IV. **Insecta.**—Insects, the most numerous and the most highly organised of invertebrates are found

FIG. 62.



Grasshopper, showing the structure and composition of an insect's body. *a*, head; *b*, eye; *c*, antenna; *d*, thorax, foremost segment; *e*, foremost pair of legs; *f*, middle segment of thorax; *g*, foremost pair of wings; *h*, second pair of legs; *i*, hindmost segment of thorax; *j*, posterior pair of wings; *k*, femur of third pair of legs; *l*, tibia; *m*, tarsus; *ab*, abdomen.

in almost every conceivable locality on the earth's surface. Scarcely a plant exists but it harbours some one of the tribe, and many animals, living or dead, supply food for other species. Insects are usually of small size and have the six foremost segments united to form a head. The three succeeding segments form a *thorax*, which alone bears the legs, one pair on each of its rings, and when wings are present they are borne by the middle and hindmost of these thoracic rings. The abdomen consists of seven segments not bearing any limbs, and followed by one, two or three abdominal rings, to which are appended the sting or its equivalent, the ovipositor. A black beetle, a blue-bottle fly, and a butterfly may be taken as types of the class.

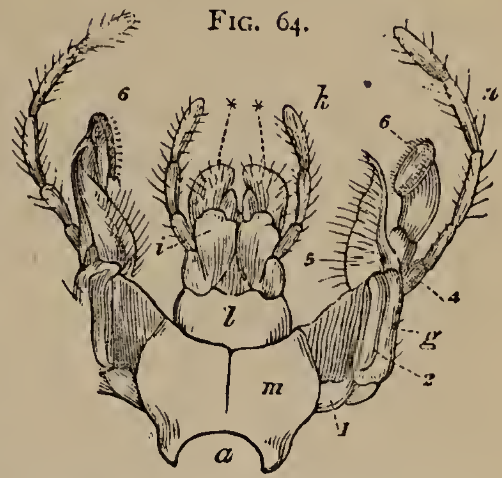
Organs of Sense.—The head of an insect bears a pair of compound eyes, and often several simple eyes in a cluster. The former have a cornea or transparent surface divided into many facets, each of the nerve rods having its own pigment mass and its own cornea. In the common house-fly there are 2000 such facets in each eye, and in the dragon-fly there are 28,000.

The head of an insect also bears one pair of *antennæ* or feelers, jointed organs which vary much in shape and structure, being sometimes simple, filiform, comb-like, or lamellar. These are organs of touch and hearing, possibly of smell and taste, and also of communication between one insect and its fellow.

Mouth.—The mouth is on the fore and under part of the head and varies in shape according to the method whereby the insect obtains its food. In beetles, dragon-flies, &c., the mouth is armed with chewing jaws. There are two lips, an upper or labrum (fig.

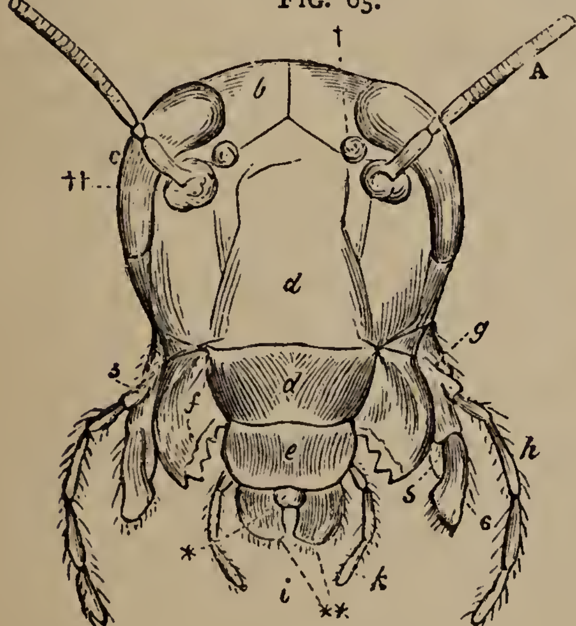
65, *e*) and lower or labium. The lower (*i*) represents the second pair of maxillæ in the lobster and crayfish, which here are united together, but sometimes as in cockroaches (fig. 64) and locusts remaining separate. The labium bears a pair of feelers called labial palps (*k*). Between the labrum and the labium are two pairs of jaws placed vertically, so that

Fig. 64.



Under side of mouth of Cockroach. *h*, maxillary palp; *i*, ligula; * paraglossæ; *k*, labial palp; 1, cardo of hinge; 2. stipes; 5, maxilla; 6, galea, or sensitive process of maxilla.

Fig. 65.



Upper side of head of Cockroach. *b*, epicranium, or top of the head; *d*, clypeus; *e*, labrum; *f*, mandibles: A, antennæ.

Fig. 66.

Mouth of Flea. Showing the slender style-like labrum between the long mandibles medially, and the labial and maxillary palps laterally.

in acting they move in a horizontal plane. The upper pair are named mandibles or biting jaws, the lower pair maxillæ or chewing jaws. The last-named have usually appended to them on each side a pair of small jointed feelers or maxillary palps. In the bluebottle and house-fly the lower lip is lengthened into an elongated gutter-like sheath in which are contained the maxillæ and mandibles, which are reduced to mere bristle-like processes.

In the bee (fig. 77, p. 132) the upper lip and mandible are strong and fitted for chewing, while the maxillæ and lower lip are long and channelled, so that when placed in apposition they make a tube through which the insect sucks in honey. In these creatures the lower lip consists of two parts, an upper or tongue and a hinder part or mentum. In the butterfly, the mouth has lost all trace of its chewing function and the maxillæ form two half tubes, and when opposed as they always are they make up a canal, and being very long and curved, this is sometimes called the proboscis. Each of these maxillæ has within it also a fine tube, and thus a transverse section through the proboscis shows three tubes, one medial between the maxillæ and one lateral on each side within each maxilla. Behind this proboscis lies the labium, which has usually large palps between which the proboscis lies when retracted ; for, unlike the tube in the bee, this proboscis is freely retractile.

Fig. 67.

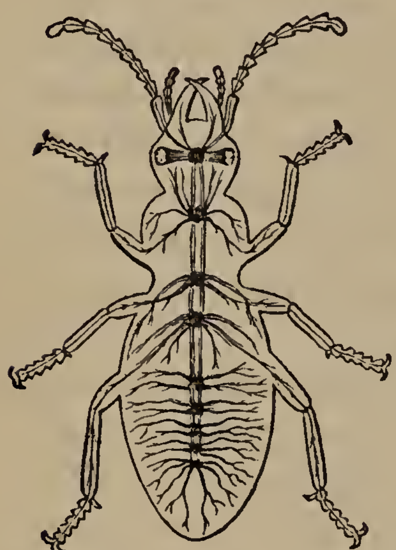
Head and proboscis of Butterfly, showing antennæ and eyes.

Body.—The head is joined to the thorax by a narrow neck, and this region is generally strong, and the limbs are attached to the under part of the side of each of its three rings. Each limb is composed of five joints : hip (*coxa*), a ring segment (*trochanter*), thigh (*femur*, fig. 63, *k*), a shin (*tibia*), and a *tarsus* of several joints ending in the claws to which sucking cushions or pads may be appended. The wings are jointed to the middle and hinder rings of the thorax; these are modified lateral flaps of the body wall, such as exist in some crustaceans; the thin skin folds of which they consist are supported by chitinous ribs (*costæ*) containing branches of the tracheæ.

Internal Structure.—On the sides of each abdominal ring are the apertures of the long, finely branching tracheæ, which sink into the body and are distributed widely among the tissues. Each tube has a membranous wall strengthened by a coiled spiral chitinous thread which keeps it open for conveying air from the surface through the body. Each motion of the body by altering the tension of the vessels promotes this method of respiration. The dorsal tubular heart placed in the abdomen, consists of a chain of chambers separated the one from the other by valves. This receives the impure blood and the new blood from the intestines, and propels it by the chief blood-vessels into lacunæ or interspaces between the tissues which are thus nourished. The blood is colourless, or green, rarely red.

Insects have two large and complex nerve ganglia in the head, and ganglia in all the segments from the head backwards. The head ganglia send branches to the eyes and appendages, while the thoracic ganglia supply the limbs. Some cave-dwelling insects have no eyes, others have these organs rudimental. The digestive canal of insects consists of a stomach to which the long œsophagus or gullet leads from the mouth; to this a thin walled sac or sucking stomach may be appended as in butterflies, in others there is a gizzard with hard horny tooth-like processes, and this is followed by the glandular thin-walled true digestive stomach which ends in an intestine, whose length depends on the nature of the food, being longer in those that feed on solid than in those that feed on fluid matter, and longer in the herbivorous than in the predaceous forms. Glandular tubes opening into the end of the intestine exist in many insects, and from their first describer are known as Malpighian.

FIG. 68.



Nervous system of Beetle, showing central double nerve cord and chain of ganglia.

Some insects are luminous. In the glow-worm (*Lampyris noctiluca*) there is a large fatty body in the abdomen richly supplied with tracheæ and nerves from which a bright light is emitted. The fire-fly (*Elater noctilucus*) sends out light from two oval spots on the thorax. Grasshoppers and crickets emit sounds by rubbing one part of the

FIG. 69.

Glow-worm, female and male.

body against another, and such have usually a special hearing organ which in crickets and locusts is placed under the knee on the outside of the foremost pair of limbs.

Development and Metamorphoses.—Insects' eggs have often a sculptured shell, and are laid in such places as are suitable for the supply of food to the newly hatched larvæ. For this egg-laying the parent has often an organ formed of the modified appendages of the abdomen. These organs are in the form of bristles, pincers, or saws, and by these the insect prepares the place for and deposits its eggs; hence, the organ is called an ovipositor.

The young of most insects emerge from the eggs as worm-like animals called caterpillars or larvæ. These are little jointed creatures, having a head which bears eyes and a pair of antennæ. Its mouth is armed with strong jaws, and the surface is often covered with bristles. Each of the three anterior segments of the body of a caterpillar is usually provided with a pair of little stumpy feet, and sometimes, as in the larvæ of butterflies, flies and saw-flies, the hinder joints have also foot-like processes. Caterpillars are most voracious in their habits and grow rapidly, frequently moulting or shedding their skin. On reaching the limit of size, many caterpillars begin to spin for themselves a case or cocoon. The glands from which this proceeds are two long tubes placed behind the head, but opening on the lip, and the material of the cocoon is silk. When caterpillars are fully fed they give up eating, and their skin thickening they become fixed and rigid and are known as pupæ, or from their occasional metallic lustre, chrysalides. In this pupa stage the animal lies for a considerable time; this skin then bursts and the perfect insect emerges, at first soft and moist but soon becoming firm and fit for independent life.

Caterpillars differ much in structure from the adult insect; thus the digestive canal of the caterpillars of butterflies is fitted for the digestion of solid food, while that of the imago or perfect insect is only fitted for sucking the juices of plants. The antennæ likewise of caterpillars are attached to the front edge of the forehead shield, and outside the articulation of the mandible, whereas the antennæ of the imago or perfect insect is articulated further forward, and on a plane with the joint at the base of the mandible; thus the antennæ of the caterpillar represent the long antennæ of the crab and lobster, while those of the perfect insect represent the antennule of crustaceans. Insects display an amount of intelligence far superior to that of the lower vertebrates; ants, wasps, and bees, the most highly organised as well as the most intelligent of the class, exhibit a wonderful power in the mode of ordering and governing their communities, and the skill shown in the construction of their habitations is scarcely inferior to that of man himself.

There are at least thirteen orders of insects known to the naturalist, a few of the commoner and more interesting representatives of which are shortly described in the next two chapters.

CHAPTER XXIII.

ORDERS OF INSECTS.

ORDER I. **Rhynchota.**—This group consists of those insects which either undergo no metamorphoses or a very slight change in the process of growth. They have almost all suctorial mouths (fig. 70), consisting of a long tubular labium, whose base is open or covered by the labrum like a little lid. The mandibles and maxillæ are altered into piercers or bristles which work within the tube. A few, however, like the bird-lice, have hook-like mandibles and chewing mouths. Many of the insects of this order are parasites and wingless, such as lice and bugs; others, the aphides, the small green insects which are so abundant on roses, geraniums, &c., are plant parasites.

FIG. 70.

Mouth of Bug.
Showing the median elongated labium, the four bristle-like mandibles and maxillæ, also, at the sides, the antennæ and eyes.

These aphides are marvellously prolific, a single pair being capable in one year of producing a progeny of twenty thousand millions or even more. Some aphides have glandular tubes on the abdomen which secrete a sweet honey-like fluid. This fluid is used as food by some species of ants, especially in this country by the red and yellow ants, which can be seen to 'milk' the honey tubes with their antennæ and swallow the fluid. Several species of aphides appear to be kept as 'milch kine' by these ants, and are fed by them apparently for this secretion.

Other representatives of this order are the cochineal and lac insects, the 'water boatmen' and 'water scorpions,' as well as the numerous and often brightly coloured field bugs.

ORDER II. **Thysanura.**—Spring-tails, an unimportant group, consisting mostly of very small creatures, sugar-lice and spring-tails, which live in dark, damp cellars, or in sugar stores, and can be seen hopping or springing about and shunning the light.

They scarcely undergo metamorphoses, and their mouths are suited for chewing. The extremity of the abdomen is prolonged into a pair of bristles or a forked tail, whereby the animal is enabled to progress by leaping. The scales of the bodies of some of these Poduræ or spring-tails are marked with very minute furrows.

ORDER III. **Euplexoptera.**—This order includes the earwigs, which are remarkable for their curiously folded hind wings, that lie folded like a fan under cover of the hard-shielded forewings. They have a masticating mouth, and posteriorly there is a pincer-like long abdominal appendage in both male and female. The earwig is remarkable for sitting on her eggs to hatch them, and for the maternal protection which the female exercises over her young which resemble her except in the absence of wings.

ORDER IV.—**Thysanoptera**, or fringe-winged insects, including a not uncommon little fly, named Thrips, whose contact with the face in warm weather is often a source of considerable itching from the titillation caused by its plumose wings and bristled body. One species of this order by piercing the immature wheat grain with its bristle-like mandibles causes the seed to shrivel, and occasionally destroys even the corn stalks.

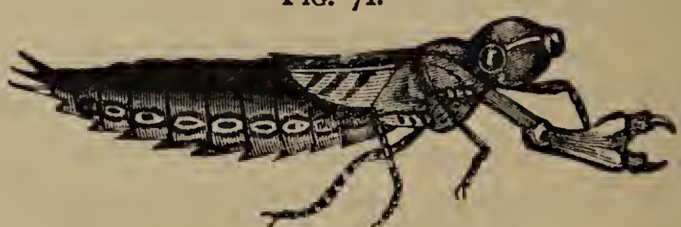
ORDER V.—**Orthoptera**, straight-winged insects, includes cockroaches, grasshoppers and locusts. These have four wings, of which the often parchment-like front pair are the smaller; the second pair are usually large, and when at rest are folded like a fan. The mouth is masticatory and both pairs of maxillæ are free. Some of the tropical forms of this order are wingless and assume extraordinary forms, the walking leaves, mantis, and walking stick (*Bacterium*) sometimes resembling dry twigs or bits of branches. In the common cockroach (*Periplaneta orientalis*) which is a native of the East, the legs are fitted for running and have spiny tibiæ, the head is overlapped by the front segments of the thorax and bears long antennæ, and the parts of the mouth are distinct (figs. 64, 65). The wings are very small, especially in the females. The Drummer Cockroach of the West Indies adds to its other disagreeable qualities that of making a knocking noise, which is sometimes sufficiently loud to keep awake the inhabitants of houses infested with these insects. Troctes pulsatorius, a minute insect found in books, old pictures, &c., also produces a sound which has earned for it the name 'death-watch' or 'death-tick.'

Locusts are terrible scourges in tropical countries, devouring all vegetation and leaving bare the regions over which they pass. Their body is long and laterally compressed and the long hind legs act as leaping organs. They produce a chirping sound by rubbing the thighs against the elevated ribs of their wings. In the grasshopper and cricket a similar sound is produced by the rubbing together of spots on the wings provided with raised ridges.

The white ants or Termites of tropical regions also belong to this order, and build ant-hills of extraordinary size and hardness. Their colonies are very complex, and consist of several kinds of inhabitants, females, males, workers and soldiers.

The dragonflies, which also belong to this order, have aquatic larvæ, breathing by means of tracheal

FIG. 71.



Larva of Dragonfly, showing the 'Mask.'

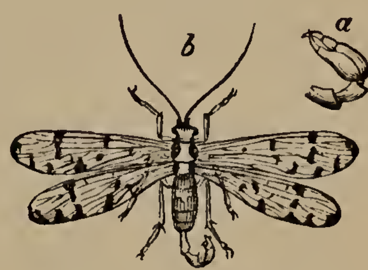
gills or tuft-like processes of their body-wall containing tracheæ, but with no openings. These processes are lost in the perfect insect; in one American genus, however, these appendages are retained during life. The larva of the common dragon-fly has a long and jointed under lip, which is folded over the face when at rest and is called the mask, but when the animal is feeding it becomes extended as a formidable tongs-like weapon for the grasping of prey (fig. 71).

CHAPTER XXIV.

INSECTS WHICH UNDERGO PERFECT METAMORPHOSES.

The four orders of insects which follow are small, but contain some interesting forms which deserve a passing notice.

Fig. 72.



Panorpa, or Scorpion-fly.

Order VI. **Neuroptera,** nerve-winged insects, including the scorpion-flies (fig. 72), snake-flies, and ant-lions. These in their perfect stage possess a mouth fitted for chewing, and four equal membranous wings, of which the hinder pair are never folded. Few of these insects are natives of this country.

Order VII.—**Trichoptera**, including the caddis-flies which have hair-clad or scaly unequal wings, the hinder of which are folded. Their larvæ agglutinate small shells, stones, straws &c. by silken threads secreted by a small spinning gland placed on the lower lip, and of these they make cases in which they live. Having attained its full size, the pupa fixes its case under water and spins a silken network or grating over each end of it, thus shutting itself in for its pupa sleep, while it does not exclude the water which it requires for breathing. After this stage of rest the pupa by its strong jaws bites through its prison, and after moulting assumes its adult form.

Order VIII.—**Strepsiptera** includes the curious parasites which live on the abdomen of bees and wasps. In these the males have four wings, two in front, small and twisted, from which the order is named, two behind, large and fan-like ; the females never lose their last pupa-skin, and are wingless, with a worm-like abdomen and are viviparous.

ORDER IX. **Aphaniptera.**—Includes fleas which have laterally compressed bodies and exceedingly rudimental wings, the scale-like traces of which are with difficulty noticeable. The suctorial mouth (fig. 66), without upper lip, has long slender saw-like mandibles, which are sheathed by the three-jointed labial palps at their base.

The antennæ are very small and lie in a groove, but the maxillary palps are large and prominent. The hindmost pair of limbs are long, muscular, and well-fitted for leaping. The larvæ are white footless grubs which feed on animal matter for about twelve days, spin for themselves a cocoon, and pass to the pupa stage. After about fourteen days' quiescence in this stage the perfect insect emerges. In many respects the flea is closely allied to the next order.

ORDER X.—**Diptera**, two winged flies, including flies, gnats, mosquitoes, &c. In this order the hind pair of wings is rudimental and represented by scale-like or pin-like processes under the developed pair of wings, and the mouth is a proboscis. The larvæ are footless, often headless maggots, such as are found on putrid meat. Some forms of Diptera, like the gnats and mosquitoes, are provided each with a long proboscis enclosing six long sharp bristles. The larvæ of the gnats are aquatic and breathe air by means of a tube with which they are provided which opens at the surface of the water. Some of these insects are very destructive to vegetation; the larvæ of the common daddy-longlegs for instance, feeds on the roots of grass and will thus sometimes destroy large patches of meadow. The Hessian fly is still more formidable, often destroying whole fields of wheat by attacking the young plants before they are in flower.

ORDER XI.—**Lepidoptera,** is also a large order, and includes those most beautiful of all insects, the butterflies, characterised by possessing four wings covered with fine dust-like scales. These microscopic scales overlap each other on the surface of the wings, and are of different shapes in different species. Butterflies have suctorial mouths (fig. 67), the proboscis-like sucker being rolled up when not in use. The larvæ or caterpillars consist of thirteen joints and are very unlike in mouth, structure, and general appearance to the perfect forms which emerge from them.

On the lower lip in the larvæ of some moths there is the outlet of two spinning glands, which when the larva has reached its full size secrete the material for a silken cocoon within which it is enclosed in the pupa state.

These insects vary in size; some, as the clothes moths and fur moths, are very small.

The larvæ of the leaf-rollers, a form nearly allied to the clothes-moth, roll up the leaves of plants on which they feed into tubes, within which they live and pass their pupa sleep, and whence they emerge in due time as little broad-winged moths.

Another related form often found on apple trees is the looper or canker-worm moth, named from the peculiar looped attitude which the larva assumes in walking. The silkworm moth, a native of North China, secretes by its two glands the silk of commerce. The sphinx moths, called so from the attitude in which the cater-

FIG. 73.

Chrysalis.

FIG. 74.

Deilephila Elpenor, Hawk Moth.

pillars are often found, with their heads and fore parts raised, are known by their prismatic antennæ and by the long horn on the tail end of the caterpillar. One of these, the tomato or tobacco sphinx moth (whose large green larva feeds on leaves of those plants) bears on each side of its abdomen five large yellow patches.

While nearly all moths are nocturnal, the true butterflies, recognised by their brighter colours and their club-shaped antennæ, are diurnal in their habits.

The best known examples are the white cabbage butterfly, the nettle tortoiseshell, and the thistle painted lady butterflies. The larvæ of the true butterflies do not spin a cocoon.

ORDER XII. **Coleoptera.**—Beetles form numerically the largest sub-division of the animal kingdom, there being over seventy thousand species. In these the fore wings are converted into a hard thick pair of wing-covers or *elytræ* overlapping the hinder pair, which are membranous, folded, and usually capable of flight. Beetles are found in almost every condition and feed on almost every kind of material; cayenne pepper, cantharides, medicinal rhubarb, animal effete matter, putrid flesh and decaying vegetables are the favourite nourishment of some forms.

FIG. 75.

Coccinella, or Ladybird perfect insect, larva, and pupa.

There are forty-eight families included in this 'polymorphic' order; one of these contains the little ladybird or *Coccinella*, whose spotted bodies are often seen on nettles in pursuit of the aphides on which they feed. It has only three large joints in the tarsus of each foot. The destructive Colorado or potato beetle (*Doryphora*) somewhat resembles the ladybird but is ten-striped and not spotted. Many beetles are extremely destructive to vegetation, both in their larval and perfect states, the strong mandibulate mouths being able to cut even hard woods. Of these, the turnip-fly, the wire-worm (which is the larva of the beetle called *Agriotes*), the pine-beetle, the typographic beetle, Scolytus the elm-beetle, Lymexylon the oak-beetle, are illustrations.

Other beetles are found in articles of food, such as *Tenebrio*, the meal-worm often found in ships' biscuits, *Dermestes*, or the bacon grub; others are the pests of museums, like the little *Anthrenus* or *Ptinus* the herbarium beetle, and *Ptilinus*, the bookworm. A few are temporary parasites; thus the larva of Rhipidius lives in the abdomen of the cockroach. Some beetles are luminous, such as the glowworm and the firefly.

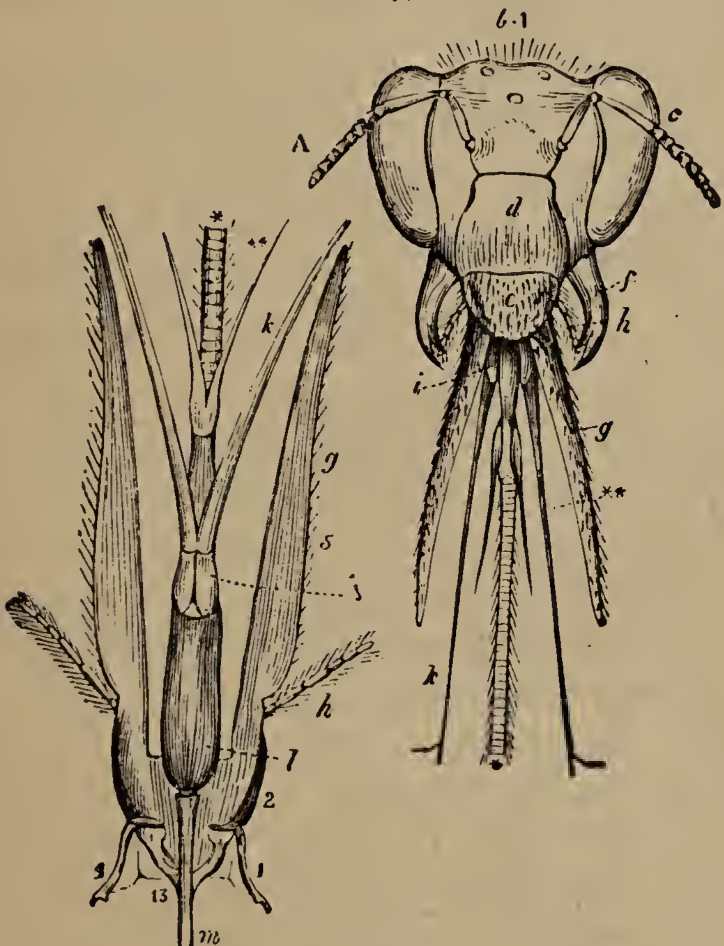
Fig. 76.

The blistering beetle (*Cantharis vesicatoria*).

Some beetles emit an ammoniacal smell when irritated; others, like Meloë, secrete a drop of acrid oil under the same circumstances. This secretion renders the bodies of some of them useful in medicine for blistering purposes; thus the bodies of Cantharis vesicatoria (fig. 76) are the Spanish or blistering flies of commerce. Some species of beetles inhabit caves and are eyeless; others are aquatic and fitted for swimming. The sizes of beetles are also exceedingly variable; some, like the large Hercules beetle, being nearly six inches long, while others are of microscopic dimension. The antennæ are of very variable shapes and sizes, being in some much longer than the body, in others very short and inconspicuous; in some, like the common cockchafer, lamellar, in others stag-horn-shaped, &c.

Order XIII.—**Hymenoptera** (membrane-winged) includes bees, wasps and ants, and in these the complexity and intelligence of the class culminates. They are characterised by having four naked membranous wings, with few veins, and a mouth with strong mandibles but with suctorial labium and maxillæ. The abdomen is often joined to the thorax by a narrow foot-stalk and the abdominal tip is modified into a sting which consists of two poison glands opening

FIG. 77.



1. Mouth of the Bee. *d*, clypeus ; *e*, labrum ; *f*, mandible ; *g*, *h*, maxilla and its palp ; *, lingua ; **, paraglossæ. 2. Tongue, more highly magnified.

into a common vesicle whose duct is elongated into a tube provided with a piercer barbed at the point.

In bees the wings are not folded and the basal joint of the hindermost tarsus is flattened and often bristle-clad to collect the pollen for the food of larvæ;

hereby many of them lay the vegetable kingdom under great obligation, as they convey the pollen from flower to flower and thereby fertilise the seeds of many plants. Many bees secrete wax by means of a wax gland placed in the abdomen, and with this material they build their hexagonal cells for the shelter of their eggs and larvæ.

The common humble bee makes a nest of moss; others use clay or wood ; and some, like cuckoos, lay their eggs in the nests of other species.

In the hives of the common honey bee the inhabitants are of three kinds, the queen or perfect female, the drones or males, and the workers or imperfect females.

Wasps have no special organ for the collection of the pollen, and have their wings longitudinally folded; they also have a more slender petiole or stalk joining the abdomen and thorax. Many of these also live in colonies, making nests of paper formed of vegetable matter chewed by their jaws into a pulp and moulded into hexagonal cells with rounded bases. Other examples are the saw-flies which have a saw-like organ for the deposition of their eggs, and the Ichneumons, which have the singular instinct of laying their eggs in the bodies of the larvæ of other insects, so that the young are hatched in the midst of abundant food, for they feast upon the tissues of their host and barely leave him enough of organ to prolong existence until they are ready for emergence.

Other Hymenopterous insects lay their eggs under the cuticle of plants; and thereby form small tumours or galls. One such species infests the oak and produces the nut-galls so important in the manufacture of ink. Another species attacks the rose, and a singular gall-fly has a cuckoo-like habit of laying its eggs in the galls formed by other insects.

The ants are probably the most intelligent of insects, having the most complex social organisation and possessing the most complex nervous system in proportion to their size of any invertebrate. The males and females are winged, the workers are wingless, and their sting gland secretes formic acid, the material whereby they irritate or sting. No group of animals are better worthy of study, and their house-building and polity, slave-holding, aphis-cow-keeping, and other habits have long been favourite subjects of observation with entomologists.

The ants form a fitting termination to the Invertebrata, as in intelligence and in interest they may be looked on as bearing to the other invertebrates something of the relation which man has to his neighbouring vertebrates.

Recapitulation.—The sub-divisions of insects are by some looked upon as deserving of a higher than ordinal rank, but as the nature of a group depends on the nature of the range of organic structure in the forms comprehended therein, and not on the number of included individuals, we cannot but see that, in each order of insects, the component species are constructed so much on one type as to forbid us from making of them more than ordinal groups.

The orders of insects which we have briefly noticed may be summarised as follows :

A. Insects with imperfect or no metamorphoses.

a. With suctorial mouths, wings absent, or when present having the fore pair thickened. Order Rhynchota.

Wings four equal, membranous. Order Thysanoptera.

b. With masticatory mouths, abdomen with a terminal appendix of bristles or a bifid tail. No wings. Order Thysanura.

Abdomen with a terminal two-bladed forceps. Order Euplexoptera.

Abdomen with no appendages, wings with reticulated costæ. Order Orthoptera.

B. Insects which pass through a quiescent pupa stage.

a. Mouth masticatory, wings membranous, equal. Order Neuroptera.

Wings hair-clad or scaly, unequal. Order Trichoptera.

Fore-wings converted into hard wing-covers. Order Coleoptera.

b. Mouth suctorial, with rudimental wings and compressed bodies. Order Aphaniptera.

With two wings. Order Diptera.

With four wings, the anterior short, twisted. Order Strepsiptera.

Wings large and scale-covered. Order Lepidoptera.

Wings naked, membranous, few-veined. Order Hymenoptera.

INDEX AND GLOSSARY.

J.E.H.