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A MANUAL OF ZOOLOGY.

Vol. I.—Invertebrate Animals.

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A MANUAL OF ZOOLOGY

FOR THE USE OF STUDENTS.

WITH A

General Introduction on the Principles of Zoology.

BY

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Dedicated

TO

JOHN HUTTON BALFOUR, M.D., F.R.S., &c.

PROFESSOR OF BOTANY IN THE UNIVERSITY OF EDINBURGH,

AS A MARK OF RESPECT

FOR HIS EMINENT SERVICES TO SCIENCE

AND OF GRATITUDE

FOR HIS MANY KINDNESSES TO THE AUTHOR.

PREFACE.

In bringing out the present work, the Author has been mainly guided by the recollection of his own difficulties as a student, and by the belief that he is supplying a distinct want. Many excellent and original works on Natural History are extant, but they mostly labour under disadvantages which more or less disqualify them as text-books for students. So vast, for instance, have been the additions to our Zoological knowledge within the last few years, that no work on Natural History, except the most recent ones, represents adequately the present state of the Science. Under this inevitable disqualification all the older Manuals labour. Other works, again, of the most profound research, are unsuitable for ordinary students from their bulk, cost, and, more than all, from their very profundity.

The Author's aim, therefore, has simply been, to present to the ordinary student those leading facts in Natural History, the knowledge of which is essential, but which lie scattered through the pages of other larger and more costly works, inaccessible to those who merely desire to learn the outlines of the Science. In carrying out this object, it is unnecessary for the Author to remark that he does not lay any claim to originality. He trusts, however, that he has succeeded in laying before his readers, not a mere mass of undigested facts, but something like an orderly and systematic review of the main points required to be known by the student. The Author is conscious of many imperfections in his plan, and also in the execution of his plan. The subject, however, is so extensive and so constantly changing that he can reasonably claim some indulgence, if the brief leisure-time of a busy life has not enabled him in every respect to keep abreast of the latest discoveries. Such defects as there may be, are, it is hoped, of such a nature as not to diminish the value of the work for ordinary students.

Amongst the sources upon which the Author has mainly drawn, it is, perhaps, invidious to mention one more than another. He feels, however, bound to acknowledge with gratitude the very great assistance which he has derived from the various works of Professor Huxley.

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GENERAL INTRODUCTION.

1. Definition of Biology and Zoology.

Natural History, strictly speaking, and as the term itself implies, should be employed to designate the study of all natural objects indiscriminately, whether these are organic or inorganic, endowed with life or exhibiting none of those incessant vicissitudes which collectively constitute vitality. So enormous, however, have been the conquests of science within the last century, that Natural History, using the term in its old sense, has of necessity been divided into several more or less nearly related branches.

In the first place, the study of natural objects admits of an obvious separation into two primary sections, of which the first deals with the phenomena presented by the inorganic world, whilst the second is occupied with the investigation of the nature and relations of all bodies which exhibit life. The former department concerns the geologist and mineralogist, and secondarily the naturalist proper as well; the latter department, treating as it does of living beings, is properly designated by the term *Biology* (from *βίος*, *life*, and *λόγος*, *a discourse*). Biology, in turn, may be split up into the sciences of Botany and Zoology, the former dealing with plants, the latter with animals; and it is really *Zoology* alone which is now-a-days understood by the term Natural History.

In determining, therefore, the limits and scope of Biology, we are brought at the very threshold of our inquiry to the question, What are the differences between inorganic and organic bodies; or rather, in the first place, what are the characteristics of an organised as compared with an unorganised body?

2. Differences between Organised and Unorganised Bodies.

In determining this somewhat difficult point, it will be best to examine the differences between organised and unorganised bodies *seriatim*, and to compare them together systematically under the following heads :—

a. Chemical composition.—Inorganic bodies are composed of many elements, which may be either simple or combined; but the combinations are limited to a small number of elements (forming binary and ternary compounds), and these are united in low combining proportions. Thus carbonate of lime, or common limestone, is an excellent example of an inorganic body,* being a ternary compound composed of one atom of the metal calcium, three of oxygen, and one of carbon.

Organised bodies, on the other hand, are composed of few chemical elements, and these are almost always combined. Furthermore, the combinations are always complex (ternary and quaternary compounds), and the elements enter into union in high combining proportions. Finally, the combinations are invariably characterised by the presence of water, and are prone to spontaneous decomposition. Thus, the great organic compound, albumen, is composed of 144 atoms of carbon, 110 of hydrogen, 18 of nitrogen, 2 atoms of sulphur, and 42 of oxygen. Iron, however, exists in the blood, very probably in its elemental condition, and copper has been detected in the liver of certain mammalia, and largely in the red colouring-matter of the feathers of certain birds.

b. Arrangement of Parts.—Unorganised bodies are composed of an aggregation of homogeneous parts (when unmixed) which bear no definite and fixed relations to one another.

Organised bodies are composed of heterogeneous parts, the relations of which amongst themselves are more or less definite.

c. Form.—Unorganised bodies are either of no definite shape —when they are said to be 'amorphous'—or they are crystalline, in which case they are almost invariably bounded by plane surfaces and straight lines. Organised bodies are always more or less definite in shape, presenting convex and concave surfaces, and being bounded by curved lines.

d. Mode of Increase.—When unorganised bodies increase in size, as crystals do, the increase is produced simply by what is called 'accretion,' that is to say, by the addition of fresh particles from the outside.

Organised bodies increase by what is often called the 'intussusception' of matter; in other words, by the reception of matter into their interior and its assimilation there. To this process alone can the term 'growth' be properly applied.

e. Cyclical Change.—Inorganic bodies exhibit no actions that

* In another sense limestone may be said to be organic, namely, when it has been produced by the operations of living beings; but this does not affect the above definition.

are not purely physical or chemical, and they show no tendency to periodical vicissitudes. Organised bodies are preeminently distinguished by the tendency which they show to pass through spontaneous and cyclical changes.

To sum up, all bodies which are composed of an aggregation of diverse but definitely related parts, which have a definite shape, bounded by curved lines and presenting concave and convex surfaces, which increase in size by the intussusception of foreign particles, and which pass through certain cyclical changes, are *organised*; and it is with the study of bodies such as these that Biology is concerned.

3. Nature of Life.

We have next to determine—and the question is one of great difficulty—what connection exists between organisation and life. Is organisation, as we have defined it, essential to the manifestation of life, or can vital phenomena be exhibited by any body which is devoid of an organised structure? In other words, is life the *cause* of organisation, or the *result* of it? And first, what do we mean by life?

Life has been variously defined by different writers. Bichat defines it as 'the sum total of the functions which resist death;' Treviranus, as 'the constant uniformity of phenomena with diversity of external influences;' Duges, as 'the special activity of organised bodies;' and Beclard, as 'organisation in action.' All these definitions, however, are more or less objectionable; since the assumption underlies them all that life is inseparably connected with organisation. In point of fact, no rigid definition of life appears to be at present possible, and it is best to regard it as being simply a tendency exhibited by certain forms of matter, under certain conditions, to pass through a series of changes in a more or less definite and determinate sequence.

As regards the connection between life and organisation, it appears that whilst all organised bodies exhibit this tendency to change, and are therefore alive, all living beings are not necessarily organised. Many of the lowest forms of life (such as the Foraminifera amongst the Protozoa) fail to fulfil one of the most essential conditions of organisation, being devoid of definite parts or organs of any kind. Nevertheless, they are capable of manifesting all the essential phenomena of life; they are produced from bodies like themselves; they eat, digest, and move, and exhibit distinct sensibility to many external impressions. Furthermore, many of these little masses of structureless jelly possess the power of manufacturing for themselves, of lime, or of the still more intractable flint, external shells of surpassing beauty and mathematical regularity. In the face of these facts, we are therefore compelled to come to the conclusion that life is truly the *cause* and not the consequence of organisation; or, in other words, that organisation is not an intrinsic and indispensable condition of vital phenomena.

Such an intrinsic and indispensable condition is, however, according to Huxley, to be found in the presence of a uniform 'physical basis,' to which he has applied the name of 'protoplasm.' Without such a material substratum or medium upon which to work no one vital phenomenon can be exhibited. The necessary forces may be there, but in the absence of this necessary vehicle there can be no outward and visible manifestation of their existence. Life, therefore, *as we know it, and as far as we know it*, may be said to be inseparably connected with protoplasm.

As regards its nature, protoplasm, though capable of forming the most complex structures, does not necessarily exhibit anything which can be looked upon as organisation or differentiation into distinct parts; and its chemical composition is the only constant which can be certainly stated. It consists, namely, in all its forms, of the four elements, carbon, hydrogen, oxygen, and nitrogen, united into a proximate compound to which Mulder applied the name of 'proteine,' and which is very nearly identical with albumen or white-of-egg. It further appears probable that all forms of protoplasm can be made to contract by means of electricity, and 'are liable to undergo that peculiar coagulation at a temperature of 40°–50° centigrade, which has been called "heat-stiffening."' (Huxley.)

If we admit, then, with Huxley—and the admission requires some qualifications—that 'protoplasm, simple or nucleated, is the formal basis of all life,' there, nevertheless, remain certain conditions equally indispensable to the external manifestation of vital phenomena; though life itself, or the *power* of exhibiting vital phenomena, may be preserved for a longer or shorter period, even though these conditions be absent. These *extrinsic* conditions of vitality are *firstly*, a certain temperature varying from near the freezing-point to 120° or 130°; *secondly*, the presence of water, which enters largely into the composition of all living tissues; *thirdly*, the presence of oxygen in a free state, this, like water, appearing to be a *sine qua non* of life, though certain fungi are stated to offer an exception to this statement.

The non-fulfilment of any of these conditions for any length of time, as a rule, causes *death*, or the cessation of vitality; but, as before remarked, life may sometimes remain in a dormant or 'potential' condition for an apparently indefinite length of time. An excellent illustration of this is afforded by the great tenacity of life, even under unfavourable conditions, exhibited by the ova of some animals and the seeds of many plants; but a more striking example is to be found in the Rotifera, or Wheel-animalcules. These are minute, mostly microscopic creatures, which inhabit almost all our ponds and streams. Diminutive as they are, they are nevertheless, comparatively speaking, of a very high grade of organisation. They possess a mouth, masticatory organs, a stomach and alimentary canal, a distinct and well-developed nervous system, a differentiated reproductive apparatus, and even organs of vision. Repeated experiments, however, have shown the remarkable fact, that, with their aquatic habits and complex organisation, the Rotifers are capable of submitting to an apparently indefinite deprivation of the necessary conditions of their existence, without thereby losing their vitality. They may be dried and reduced to dust, and may be kept in this state for a period of many years; nevertheless, the addition of a little water will, at any time, restore them to their pristine vigour and activity. It follows, therefore, that an organism may be deprived of all power of manifesting any of the phenomena which constitute what we call life, without losing its hold upon the vital forces which belong to it.

If, in conclusion, it be asked whether the term 'vital force' is any longer permissible in the mouth of a scientific man, the question must, I think, be answered in the affirmative. Formerly, no doubt, the progress of science was retarded and its growth checked by a too exclusive reference of natural phenomena to a so-called vital force. Equally unquestionable is the fact that the development of Biological science has progressed cotemporaneously with the successive victories gained by the physicists over the vitalists. Still, no physicist has hitherto succeeded in explaining any fundamental vital phenomenon upon purely physical and chemical principles. The simplest vital phenomenon has in it something over and above the merely chemical and physical forces which we can demonstrate in the laboratory. It is easy, for example, to say that the action of the gastric juice is a chemical one, and doubtless the discovery of this fact was a great step in physiological science. Nevertheless, in spite of the most searching investigations, it is certain that digestion presents phenomena which are as yet inexplicable upon any chemical theory. This is exemplified in its most striking form, when we look at a simple organism like the Amœba. This animalcule, which is structurally little more than a mobile lump of jelly, digests as perfectly—as far as the result to itself is concerned—as does the most highly organised animal with the most complex digestive apparatus. It takes food into its interior, it digests it without the presence of a single organ for the purpose, and still more, it possesses that inexplicable selective power by which it assimilates out of its food such constituents as it needs whilst it rejects the remainder. In the present state of our knowledge, therefore, we must conclude that even in the process of digestion as exhibited in the Amœba there is something that is not merely physical or chemical. Similarly, any organism when just dead consists of the same protoplasm as before, in the same forms, and with the same arrangement; but it has most unquestionably lost a something by which all its properties and actions were modified, and some of them were produced. What that something is, we do not know, and perhaps never shall know; and it is possible, though highly improbable, that future discoveries may demonstrate that it is merely a subtle modification of some physical force. In the meanwhile, as all vital actions exhibit this mysterious something, it would appear unphilosophical to ignore its existence altogether, and the term 'vital force' may therefore be retained with advantage. In using this term, however, it must not be forgotten that we are simply employing a convenient expression for an unknown quantity, for that residual portion of every vital action which cannot at present be referred to the operation of any known physical force.

4. Differences between Animals and Plants.

We have now arrived at some definite notion of the essential characters of living beings in general, and we have next to consider what are the characteristics of the two great divisions of the organic world. What are the characters which induce us to place any given organism in either the vegetable or the animal kingdom? What, in fact, are the differences between animals and plants?

It is generally admitted that all bodies which exhibit vital phenomena are capable of being referred to one of the two great kingdoms of organic nature. At the same time it is often extremely difficult in individual cases to come to any decision as to the kingdom to which a given organism should be referred, and in many cases the determination is purely arbitrary. So strongly, in fact, has this difficulty been felt, that some observers have established an intermediate kingdom, a sort of no-man's-land, for the reception of those debatable organisms which cannot be definitely and positively classed either amongst vegetables or amongst animals.

In the case of the higher animals and plants there is no difficulty; the former being at once distinguished by the possession of a nervous system, of motor power which can be voluntarily exercised, and of an internal cavity fitted for the reception and digestion of solid food. The higher plants, on the other hand, possess no nervous system or organs of sense, are incapable of independent locomotion, and are not provided with an internal digestive cavity, their food being wholly fluid or gaseous. These distinctions, however, do not hold good as regards the lower and less highly organised members of the two kingdoms, many animals having no nervous system or internal digestive cavity, whilst many plants possess the power of locomotion; so that we are compelled to institute a closer comparison in the case of these lower forms of life.

a. Form.—As regards external configuration, of all characters the most obvious, it must be admitted that no absolute distinction can be laid down between plants and animals. Many of our ordinary zoophytes, such as the Hydroid Polypes, the sea-shrubs and corals—as, indeed, the name zoophyte implies—are so similar in external appearance to plants that they were long described as such. Amongst the Molluscoida, the common sea-mat (Flustra) is invariably regarded by seaside visitors as a seaweed. Many of the Protozoa are equally like some of the lower plants (Protophyta); and even at the present day there are not wanting those who look upon the sponges as belonging to the vegetable kingdom. On the other hand, the embryonic forms, or 'zoospores,' of certain undoubted plants (such as the Protococcus nivalis, Vaucheria, &c.) are provided with ciliated processes with which they swim about, thus coming so closely to resemble some of the Infusorian animalcules as to have been referred to that division of the Protozoa.

b. Internal Structure.—Here, again, no line of demarcation can be drawn between the animal and vegetable kingdoms. In this respect all plants and animals are fundamentally similar, being alike composed of molecular, cellular, and fibrous tissues.

c. Chemical Composition.—Plants, speaking generally, exhibit a preponderance of ternary compounds of carbon, hydrogen, and oxygen—such as starch, cellulose, and sugar—whilst nitrogenised compounds enter more largely into the composition of animals. Still both kingdoms contain identical or representative compounds, though there may be a difference in the proportion of these to one another. Moreover, the most characteristic of all vegetable compounds, viz. cellulose, has been detected in the outer covering of the sea-squirts, or Ascidian Molluscs; and the so-called 'glycogen' which is secreted by the liver of the Mammalia, is closely allied to, if not absolutely identical with, the hydrated starch of plants.

d. Motor Power.—This, though broadly distinctive of animals, can by no means be said to be characteristic of them. Thus, many animals in their mature condition are permanently fixed or attached to some foreign object; and the embryos of many plants are endowed with locomotive power by means of those vibratile, hair-like processes which are called 'cilia,' and are so characteristic of many of the lower forms of animal life. Not only is this the case, but large numbers of the lower plants, such as the Diatoms and Desmids, exhibit throughout life an amount and kind of locomotive power which does not admit of being rigidly separated from the movements executed by animals, though the closest researches have hitherto failed to show the mechanism whereby these movements are brought about.

e. Nature of the Food.—Whilst all the preceding points have failed to yield a means of invariably separating animals from plants, a distinction which holds good almost without exception is to be found in the nature of the food taken respectively by each, and in the results of the conversion of the same. The unsatisfactory feature, however, in this distinction is this, that even if it could be shown to be, theoretically, invariably true, it would nevertheless be practically impossible to apply it to the greater number of those minute organisms concerning which alone there can be any dispute.

As a broad rule, all plants are endowed with the power of converting inorganic into organic matter. The *food* of plants consists of the inorganic compounds, carbonic acid, ammonia, and water, along with small quantities of certain mineral salts. From these, and from these only, plants are capable of elaborating the proteinaceous matter or protoplasm which constitutes the physical basis of life. To this general statement, however, an exception must seemingly be made in favour of certain fungi, which require organised compounds for their nourishment.

On the other hand, no known animal possesses the power of converting inorganic compounds into organised matter, but all, mediately or immediately, are dependent in this respect upon plants. All animals, as far as is certainly known, require ready-made proteinaceous matter for the maintenance of existence, and this they can only obtain in the first instance from plants. Plants, therefore, are the great manufacturers in nature, animals are the great consumers.

Just, however, as this law does not invariably hold good for plants, certain fungi being in this respect animals, so it is not impossible that a limited exception to the universality of the law will be found in the case of animals also. Thus, in some recent investigations into the fauna of the sea at great depths, a singular organism, of an extremely low type, but occupying large areas of the sea-bottom, has been discovered, to which Professor Huxley has given the name of Bathybius. As vegetable life is extremely scanty, or is altogether wanting, in these abysses of the ocean, it has been conjectured that this organism is possibly endowed with the power—otherwise exclusively found in plants—of elaborating organic compounds out of inorganic materials, and in this way supplying food for the higher animals which surround it. The water of the ocean, however, at these enormous depths is richly charged with organic matter in solution, and this conjecture is thereby rendered doubtful.

Be this as it may, there remain to be noticed two distinctions, broadly though not universally applicable, which are due to the nature of the food required respectively by animals and plants. In the first place, the food of all plants consists partly of gaseous matter and partly of matter held in solution. They require, therefore, no special aperture for its admission, and no internal cavity for its reception. The food of almost all animals consists of solid particles, and they are, therefore, usually provided with a mouth and a distinct digestive cavity. Some animals, however, such as the tape-worm and the Gregarinæ, live entirely by imbibition of organic fluids through the general surface of the body, and many have neither a distinct mouth nor stomach

Secondly, plants decompose carbonic acid, retaining the carbon and setting free the oxygen, certain fungi forming an exception to this law. The reaction of plants upon the atmosphere is, therefore, characterised by the production of free oxygen. Animals, on the other hand, absorb oxygen and emit carbonic acid, so that their reaction upon the atmosphere is the reverse of that of plants, and is characterised by the production of carbonic acid.

Finally, it is worthy of notice that it is in their lower and not in their higher developments that the two kingdoms of organic nature approach one another. No difficulty is experienced in separating the higher animals from the higher plants, and for these universal laws can be laid down to which there is no exception. It might, not unnaturally, have been thought that the lowest classes of animals would exhibit most affinity to the highest plants, and that thus a gradual passage between the two kingdoms would be established. This is not the case, however. The lower animals are not allied to the higher plants, but to the lower, and it is in the very lowest members of the vegetable kingdom, or in the embryonic and immature forms of plants little higher in the scale, that we find such a decided animal gift as the power of independent locomotion. It is also in the less highly organised and less specialised forms of plants that we find the only departures from the great laws of vegetable life, the deviation being in the direction of the laws of animal life.

5. Morphology and Physiology.

The next point which demands notice relates to the *nature* of the differences between one animal and another, and the question is one of the highest importance. Every animal—as every plant—may be regarded from two totally distinct, and, indeed, often apparently opposite, points of view. From the first point of view we have to look simply to the laws, form, and arrangement of the *structures* of the organism, in short to its external shape and internal structure. This constitutes the science of morphology (*μορφή*, *form*, and *λόγος*, *discourse*). From the second, we have to study the vital actions performed by living beings and the *functions* discharged by the different parts of the organism. This constitutes the science of physiology.

A third department of zoology is concerned with the relations of the organism to the external conditions under which it is placed, constituting a division of the science to which the term ‘distribution’ is applied.

Morphology, again, not only treats of the structure of living beings in their fully developed condition (anatomy), but is also concerned with the changes through which every living being has to pass before it assumes its mature or adult characters (embryology or development). The term ‘histology’ is further employed to designate that branch of morphology which is specially occupied with the investigation of minute or microscopical tissues.

Physiology treats of all the functions exercised by living bodies, or by the various definite parts, or organs, of which most animals are composed. All these functions come under three heads:—1. *Functions of Nutrition*, divisible into functions of absorption and metamorphosis, comprising those functions which are necessary for the growth and maintenance of the organism. 2. *Functions of Reproduction*, whereby the perpetuation of the species is secured. 3. *Functions of Correlation*, comprising all those functions (such as sensation and voluntary motion) by which the external world is brought into relation with the organism, and the organism in turn reacts upon the external world.

Of these three, the functions of nutrition and reproduction are often collectively called the functions of organic or vegetative life, as being common to animals and plants; while the functions of correlation are called the animal functions, as being more especially characteristic of, though not peculiar to, animals.

6. Differences between different Animals.

All the innumerable differences which subsist between different animals may be classed under two heads, corresponding to the two aspects of every living being, morphological and physiological. One animal differs from another either *morphologically*, in the fundamental points of its structure, or *physiologically*, in the manner in which the vital functions of the organism are discharged. These constitute the only modes in which any one animal can differ from any other; and they may be considered respectively under the heads of Specialisation of Function and Morphological type.

a. Specialisation of Function.—All animals alike, whatever their structure may be, perform the three great physiological functions; that is to say, they all nourish themselves, reproduce their like, and have certain relations with the external world. They differ from one another physiologically in the *manner* in which these functions are performed. Indeed, it is only in the functions of correlation that it is possible that there should be any difference in the amount or perfection of the function performed by the organism, since nutrition and reproduction, as far as their results are concerned, are essentially the same in all animals. In the manner, however, in which the same results are brought about great differences are observable in different animals. The nutrition of such a simple organism as the Amœba is, indeed, performed perfectly, as far as the result to the animal itself is concerned—as perfectly as in the case of the highest animal—but it is performed with the simplest possible apparatus. It may, in fact, be said to be performed without any *special* apparatus, since any part of the surface of the body may be extemporised into a mouth, and there is no differentiated alimentary cavity. And not only is the nutritive apparatus of the simplest character, but the function itself is equally simple, and is entirely divested of those complexities and separations into secondary functions which characterise the process in the higher animals. It is the same, too, with the functions of reproduction and correlation; but this point will be more clearly brought out, if we examine the method in which one of the three primary functions is performed in two or three examples. Nutrition, as the simplest of the functions, will best answer the purpose.

In the simpler Protozoa, such as the Amœba, the process of nutrition consists essentially in the reception of food, its digestion within the body, the excretion of effete or indigestible matter, and the distribution of the nutritive fluid through the body. The first three portions of this process are effected without any special organs for the purpose, and for the last there is simply a rudimentary contractile cavity. Respiration, if it can be said to exist at all as a distinct function, is simply effected by the general surface of the body.

In a Cœlenterate animal, such as the sea-anemone, the function of nutrition has not advanced much in complexity, but the means for its performance are somewhat more specialised. Permanent organs of prehension (tentacles) are present, there is a distinct mouth, and there is a persistent internal cavity for the reception of the food; but this is not shut off from the general cavity of the body, and there are no distinct circulatory or respiratory organs.

In a Mollusc, such as the oyster, nutrition is a much more complicated process. There is a distinct mouth, and an alimentary canal which is shut off from the general cavity of the body, and is provided with a separate aperture for the excretion of effete and indigestible matters. Digestion is performed by a distinct stomach with accessory glands; a special contractile cavity, or heart, is provided for the propulsion of the nutritive products of digestion through all parts of the organism, and the function of respiration is performed by complex organs specially adapted for the purpose.

It is not necessary here to follow out this comparison further. In still higher animals the function of nutrition becomes still further broken up into secondary functions, for the due performance of which special organs are provided, the complexity of the organism thus necessarily increasing *pari passu* with the complexity of the function. This gradual subdivision and elaboration is carried out equally with the other two physiological functions, viz. reproduction and correlation, and it constitutes what is technically called the 'specialisation of functions,' though it has been more happily termed by Milne-Edwards 'the principle of the physiological division of labour.' It is needless, however, to remark that in the higher animals it is the functions of correlation which become most highly specialised, disproportionately so, indeed, when compared with the development of the nutritive and reproductive functions.

b. Morphological Type. — The first point in which one animal may differ from another is the degree to which the principle of the physiological division of labour is carried. The second point in which one animal may differ from another is in its 'morphological type,' that is to say, in the fundamental plan upon which it is constructed. By one not specially acquainted with the subject it might be readily imagined that each species or kind of animal was constructed upon a plan peculiar to itself and not shared by any other. This, however, is far from being the case; and it is now universally recognised that all the varied species of animals—however great the apparent amount of diversity amongst them — may be arranged under no more than half-a-dozen primary morphological types or plans of structure. Upon one or other of these five or six plans every known animal, whether living or extinct, is constructed. It follows from the limited number of primitive types or patterns, that great numbers of animals must agree with one another in their morphological type. It follows also that all so agreeing can differ from one another only in the sole remaining element of the question, namely by the amount of specialisation of function which they exhibit. Every animal, therefore, as Professor Huxley has well expressed it, is the resultant of two tendencies, the one morphological, the other physiological.

The six types or plans of structure, upon one or other of which all known animals have been constructed, are technically called 'sub-kingdoms,' and are known by the names Protozoa, Cœlenterata, Annuloida, Annulosa, Mollusca, and Vertebrata. We have, then, to remember that every member of each of these primary divisions of the animal kingdom agrees with every other member of the same division in being formed upon a certain definite plan or type of structure, and differs from every other simply in the grade of its organisation, or, in other words, in the degree to which it exhibits specialisation of function.

Von Baer's Law of Development.—As the study of living beings in their adult condition shows us that the differences between those which are constructed upon the same morphological type depend upon the degree to which specialisation of function is carried, so the study of development teaches us that the changes undergone by any animal in passing from the embryonic to the mature condition are due to the same cause. All the members of any given sub-kingdom, when examined in their earliest embryonic condition, are found to present the same fundamental characters. As development proceeds, however, they diverge from one another with greater or less rapidity, until the adults ultimately become more or less different, the range of possible modification being apparently almost illimitable. The differences are due to the different degrees of specialisation of function necessary to perfect the adult, and, therefore, as Von Baer put it, *the progress of development is from the general to the special.*

It is upon a misconception of the true import of this law that the theory arose, that every animal in its development passed through a series of stages in which it resembles, in turn, the different inferior members of the animal scale. With regard to man, standing at the top of the whole animal kingdom, this theory has been expressed as follows :—'Human organogenesis is a transitory comparative anatomy, as, in its turn, comparative anatomy is a fixed and permanent state of the organogenesis of man.'—(Serres.) In other words, the embryo of a vertebrate animal was believed to pass through a series of changes corresponding respectively to the permanent types of the lower sub-kingdoms—namely, the Protozoa, Cœlenterata, Annuloida, Annulosa, and Mollusca—before finally assuming the true vertebrate characters. Such, however, is not truly the case. The ovum of every animal is from the first impressed with the power of developing in one direction only, and very early exhibits the fundamental characters proper to its sub-kingdom, never presenting the structural peculiarities belonging to any other morphological type. Nevertheless, the differences which subsist between the members of each sub-kingdom in their adult condition are truly referable to the degree to which development proceeds, the place of each individual in his own sub-kingdom being regulated by the stage at which development is arrested. Thus, many cases are known in which the younger stages of a given animal *represent* the permanent adult condition of an animal somewhat lower in the scale. To give a single example, the young Gasteropod (amongst the Mollusca) transiently presents all the essential characters which permanently distinguish the adult Pteropod. The development of the Gasteropod, however, proceeds beyond this point, and the adult is much more highly specialised than is the adult Pteropod.

7. Homology, Analogy, and Homomorphism.

When organs in different animals agree with one another in fundamental *structure*, they are said to be 'homologous;' when they perform the same functions they are said to be 'analogous.' Thus the wing of a bird and the arm of a man are constructed upon the same fundamental plan, and they are, therefore, homologous organs. They are not analogous, however, since they do not perform the same function, the one being adapted for aerial locomotion, the other being an organ of prehension. On the other hand, the wings of a bird and the wings of an insect both serve for flight, and they are, therefore, analogous, since they perform the same function. They are not homologous, however, as they are constructed upon wholly dissimilar plans. There are numerous cases, however, in which organs correspond with one another both structurally and functionally, in which case they are both homologous and analogous.

A form of homology is often seen in a single animal in which there exists a succession of parts which are fundamentally identical in structure, but are variously modified to fulfil different functions. Thus a Crustacean—such as the lobster—may be looked upon as being composed of a succession of rings, each of which bears a pair of appendages, these appendages being constructed upon the same type, and being, therefore, homologous. They are, however, variously modified in different regions of the body to enable them to fulfil special functions, some being adapted for swimming, others for walking, others for prehension, others for mastication, and so on. This succession of fundamentally similar parts in the same animal constitutes what is known as *serial homology*. When, however, the successive parts are similar to one another, both in structure and in function, the case becomes rather one of what is called 'vegetative' or 'irrelative repetition.' An excellent instance of this is seen in the common Millipede (Iulus).

Homomorphism.—Many examples occur, both among animals and among plants, in which families widely removed from one another as to their fundamental structure, nevertheless present a singular, and sometimes extremely close, resemblance in their external characters. Thus the composite Hydroid Polypes and the Polyzoa are singularly like one another; so much so, that they have often been classed together, whereas, in reality, they belong to different sub-kingdoms. Many other cases of this 'mimetic' resemblance of different animals might be adduced, and in many cases these 'representative forms' appear to be able to fill each others' places in the general economy of nature. This is so far true, at any rate, that 'homomorphous' forms are generally found in different parts of the earth's surface. Thus, the place of the Cacti of South America is taken by the Euphorbiæ of Africa; or, to take a zoological illustration, many of the different orders of Mammalia are *represented* in the single order Marsupialia in Australia, in which country this order has almost alone to discharge the functions elsewhere performed by several orders. Many mimetic forms, however, live peacefully side by side, and it is difficult to say whether in this case the resemblance between them is for the advantage or for the disadvantage of either.

8. Correlation of Growth.

This term is employed by zoologists to express the empirical law that certain structures, not necessarily or usually connected together by any visible link, invariably occur in association with one another, and never occur apart, so far, at any rate, as human observation goes.

Thus, all animals which possess two condyles on the occipital bone, and possess non-nucleated red blood-corpuscles, suckle their young. Why an animal with only one condyle on its occipital bone should not suckle its young we do not know, and perhaps we shall at some future time find mammary glands associated with a single occipital condyle. Again, the feet are cleft in all animals which ruminate, but not in any other. In other cases the correlation is even more apparently lawless, and is even amusing. Thus all, or almost all, cats which are entirely white and have blue eyes, are at the same time deaf. With regard to these and similar generalisations we must, however, bear in mind the following three points:—

1. The various parts of the organisation of any animal are so closely interconnected, and so mutually dependent upon one another, both in their growth and development, that the characters of each must be in *some* relation to the characters of all the rest, whether this be obviously the case or not.
2. It is rarely possible to assign any reason for correlations of structure, though they are certainly in no case accidental.
3. The law is a purely empirical one, and expresses nothing more than the result of experience; so that structures which we now only know as occurring in association, may ultimately be found dissociated, and conjoined with other structures of a different character.

9. Classification.

Classification is the arrangement of a number of diverse objects into larger or smaller groups, according as they exhibit more or less likeness to one another. The excellence of any given classification will depend upon the nature of the points which are taken as determining the resemblance. Systems of classification, in which the groups are founded upon mere external and superficial points of similarity, though often useful in the earlier stages of science, are always found in the long run to be inaccurate. It is needless, in fact, to point out that many living beings, the structure of which is fundamentally different, may, nevertheless, present such an amount of adaptive external resemblance to one another, that they would be grouped together in any 'artificial' classification. Thus, to take a single example, the whale, by its external characters, would certainly be grouped amongst the fishes, though widely removed from them in all the essential points of its structure. 'Natural' systems of classification, on the other hand, endeavour to arrange animals into divisions founded upon a due consideration of *all* the essential and fundamental points of structure, wholly irrespective of external similarity of form and habits. Philosophical classification depends upon a due appreciation of what constitute the true points of difference and likeness amongst animals; and we have already seen that these are morphological type and specialisation of function. Philosophical classification, therefore, is a formal expression of the facts and laws of Morphology and Physiology. It follows that the more fully the programme of a philosophical and strictly natural classification can be carried out, the more completely does it afford a condensed exposition of the fundamental construction of the objects classified. Thus, if the whale were placed by an artificial grouping amongst the fishes, this would simply express the facts that its habits are aquatic and its body fish-like. When, on the contrary, we obtain a natural classification, and we learn that the whale is placed amongst the Mammalia, we then know at once that the young whale is born in a comparatively helpless condition, and that its mother is provided with special mammary glands for its support; this expressing a fundamental distinction from all fishes, and being associated with other equally essential correlations of structure.

The entire animal kingdom is primarily divided into some half-a-dozen great plans of structure, the divisions thus formed being called 'sub-kingdoms.' The sub-kingdoms are, in turn, broken up into classes, classes into orders, orders into families, families into genera, and genera into species. We shall examine these successively, commencing with the consideration of a species, since this is the zoological unit of which the larger divisions are made up.

Species.—No term is more difficult to define than 'species,' and on no point are zoölogists more divided than as to what should be understood by this word. Naturalists, in fact, are not yet agreed as to whether the term species expresses a real and permanent distinction, or whether it is to be regarded merely as a convenient, but not immutable, abstraction, the employment of which is necessitated by the requirements of classification.

By Buffon, 'species' is defined as 'a constant succession of individuals* similar to and capable of reproducing each other.'

De Candolle defines species as an assemblage of all those individuals which resemble each other more than they do others, and are able to reproduce their like, doing so by the generative process, and in such a manner that they may be supposed by analogy to have all descended from a single being or a single pair.

M. de Quatrefages defines species as 'an assemblage of individuals, more or less resembling one another, which are descended, or may be regarded as being descended, from a single primitive pair by an uninterrupted succession of families.'

Müller defines species as 'a living form, represented by individual beings, which reappears in the product of generation with certain invariable characters, and is constantly reproduced by the generative act of similar individuals.'

According to Woodward, 'all the specimens, or individuals, which are so much alike that we may reasonably believe them to have descended from a common stock, constitute a *species*.'

From the above definitions it will be at once evident that there are two leading ideas in the minds of zoologists when they employ the term species; one of these being a certain amount of resemblance between individuals, and the other being the proof that the individuals so resembling each other have descended from a single pair, or from pairs exactly similar to one another. The characters in which individuals must resemble one another in order to entitle them to be grouped in a separate species, according to Agassiz, 'are only those determining size, proportion, colour, habits, and relations to surrounding circumstances and external objects.'

On a closer examination, however, it will be found that these two leading ideas in the definition of species—external resemblance and community of descent—are both defective, and liable to break down if rigidly applied. Thus, there are in nature no assemblages of plants or animals, usually grouped together into a single species, the individuals of which *exactly* resemble one another in every point. Every naturalist is compelled to admit that the individuals which compose any so-called species, whether of plants or animals, differ from one another to a greater or less extent, and in respects which may be regarded as more or less important. The exist-

* In using the term 'individual,' it must be borne in mind that the 'zoological individual' is meant; that is to say, the total result of the development of a single ovum, as will be hereafter explained at greater length.

ence of such individual differences is attested by the universal employment of the terms 'varieties' and 'races.' Thus a 'variety' comprises all those individuals which possess some distinctive peculiarity in common, but do not differ in other respects from another set of individuals sufficiently to entitle them to take rank as a separate species. A 'race,' again, is simply a permanent or 'perpetuated' variety. The question, however, is this—How far may these differences amongst individuals obtain without necessitating their being placed in a separate species? In other words: How great is the amount of individual difference which is to be considered as merely '*varietal*,' and at what exact point do these differences become of '*specific*' value? To this question no answer can be given; since it depends entirely upon the weight which different naturalists would attach to any given individual difference.* Distinctions which appear to one observer as sufficiently great to entitle the individuals possessing them to be grouped as a distinct species, by another are looked upon as simply of varietal value; and, in the nature of the case, it seems impossible to lay down any definite rules. To such an extent do individual differences sometimes exist in particular genera—termed 'protean' or 'polymorphic' genera—that the determination of the different species and varieties becomes an almost hopeless task.

Besides the individual differences which ordinarily occur in all species, other cases occur in which a species consists normally and regularly of two or even three distinct forms, which cannot be said to be mere varieties, since no intermediate forms can be discovered. When two such distinct forms exist the species is said to be 'dimorphic,' and when three are present it is called 'trimorphic.' Thus in dimorphic plants a single species is composed of two distinct forms, similar to one another in all respects except in their reproductive organs, the one form having a long pistil and short stamens, the other a short pistil with long stamens. In trimorphic plants, the species is composed of three such distinct forms, which differ in like manner in the conformation of their reproductive organs, though they are otherwise undistinguishable.—(Darwin.) Similar cases are known in animals, but in them the differences, though apparently connected with reproduction, are not confined to the reproductive organs. Thus the females of certain butterflies normally appear under two or

* As an example of this, it is sufficient to allude to the fact that hardly any two botanists agree as to the number of species of Willows and Brambles in the British Isles. What one observer classes as mere varieties, another regards as good and distinct species.

three entirely different forms, not connected by any intermediate links, and the same thing occurs in some of the Crustacea.

As regards, therefore, the first point in the definition of species, namely the external resemblance of assemblages of individuals, we are forced to conclude that no two individuals are exactly alike; and that the amount and kind of external resemblance which constitutes a species is not a precise and invariable quantity, but depends upon the value attached to particular characters by any given observer.

The second point in the definition of species, namely community of descent, is hardly in a more satisfactory condition, since the descent of any given series of individuals from a single pair, or from pairs exactly similar to one another, is at best but a probability, and is in no case capable of proof. In the case of the higher animals it can doubtless be shown that certain assemblages of individuals possess amongst themselves the power of fecundation and of producing fertile progeny, and that this power does not extend to the fecundation of individuals belonging to another different assemblage. Amongst the higher animals 'crosses' or 'hybrids' can only be produced between closely allied species, and, when produced, they are sterile, and are not capable of reproducing their like. In these cases, therefore, we may take this as a most satisfactory element in the definition of 'species.' The sterility, however, of hybrids is not universal, even amongst the higher animals; and amongst plants no doubt can be entertained but that the individuals of species universally admitted to be distinct are capable of mutual fertilisation; the hybrid progeny thus produced being likewise fertile and capable of reproducing similar individuals. That this fertility is often irregular, and may be destroyed in a few generations, admits of explanation, and hardly alters the significance of these undoubted facts.

Upon the whole, then, it seems in the meanwhile safest to adopt a definition of species which implies no theory, and does not include the belief that the term necessarily expresses a fixed and permanent quantity. Species, therefore, may be defined as *an assemblage of individuals which resemble each other in their essential characters, are able, directly or indirectly, to produce fertile individuals, and which do not (as far as human observation goes) give rise to individuals which vary from the general type through more than certain definite limits.* The production of occasional monstrosities does not, of course, invalidate this definition.

Genus is a term applied to groups of species which possess a community of essential details of structure. A genus may include a single species only, in cases where the combination of characters which make up the species are so peculiar that no other species exhibits similar structural characters; or, on the other hand, it may contain many hundreds of species.

Families are groups of genera which agree in their general characters. According to Agassiz, they are divisions founded upon peculiarities of 'form as determined by structure.'

Orders are groups of families related to one another by structural characters common to all.

Classes are larger divisions, comprising animals which are formed upon the same fundamental plan of structure, but differ in the method in which the plan is executed.—(Agassiz.)

Sub-kingdoms are the primary divisions of the animal kingdom, which include all those animals which are formed upon the same structural or morphological type, irrespective of the degree to which specialisation of function may be carried.

Impossibility of a Linear Classification.—It has sometimes been thought that the animal kingdom can be arranged in a linear series, every member of the series being higher in point of organisation than the one below it. As we have seen, however, the *status* of any given animal depends upon two conditions—one its morphological type, the other the degree to which specialisation of function is carried. Now, if we take two animals, one of which belongs to a lower morphological type than the other, no degree of specialisation of function, however great, will place the former above the latter, as far as its *type of structure* is concerned, though it may make the former a more highly organised animal. Every vertebrate animal, for example, belongs to a higher morphological type than every Mollusc; but the higher Molluscs, such as cuttle-fishes, are much more highly organised, as far as their type is concerned, than are the lowest vertebrata. In a linear classification, therefore, the cuttle-fishes should be placed above the lowest fishes—such as the lancelet—in spite of the fact that the type upon which the latter are constructed is by far the highest of the two.

It is obvious, therefore, that a linear classification is not possible, since the higher members of each sub-kingdom are more highly organised than the lower forms of the next sub-kingdom in the series, at the same time that they are constructed upon a lower morphological type.

10. Reproduction.

Reproduction is the process whereby new individuals are generated and the perpetuation of the species insured. The methods in which this end may be attained exhibit a good deal of diversity, but they may be all considered under two heads.

I. *Sexual Reproduction.*—This consists essentially in the production of two distinct elements, a germ-cell or ovum, and a sperm-cell or spermatozoid, by the contact of which the ovum —now said to be 'fecundated'—is enabled to develop itself into a new individual. As a rule, the germ-cell is produced by one individual (female) and the spermatic element by another (male); in which case the sexes are said to be distinct, and the species is said to be 'diœcious.' In other cases the same individual has the power of producing both the essential elements of reproduction; in which case the sexes are said to be united, and the individual is said to be 'hermaphrodite,' 'androgynous,' or 'monœcious.' In the case of hermaphrodite animals, however, self-fecundation—contrary to what might have been expected—rarely constitutes the reproductive process; and as a rule the reciprocal union of two such individuals is necessary for the production of young. Even amongst hermaphrodite plants, where self-fecundation may, and certainly does, occur, provisions seem to exist by which perpetual self-fertilisation is prevented, and the influence of another individual secured at intervals. Amongst the higher animals sexual reproduction is the only process, whereby new individuals can be generated.

II. *Non-sexual Reproduction.*—Amongst the lower animals fresh beings may be produced without the contact of an ovum and a spermatozoid, that is to say without any true generative act. The processes by which this is effected vary in different animals, and are all spoken of as forms of 'asexual' or 'agamic' reproduction. As we shall see, however, the true 'individual' is very rarely produced otherwise than sexually, and most forms of agamic reproduction are really modifications of growth.

a. Gemmation and Fission.—Gemmation, or budding, consists in the production of a bud, or buds, generally from the exterior, but sometimes from the interior, of the body of an animal, which buds are developed into independent beings, which may or may not remain permanently attached to the parent organism. Fission differs from gemmation solely in the fact that the new structures in the former case are produced by a division of the body of the original organism into separate parts, which may remain in connection, or may undergo detachment.

The simplest form of gemmation, perhaps, is seen in the power possessed by certain animals of reproducing parts of their bodies which they may have lost. Thus, the Crustacea possess the power of reproducing a lost limb, by means of a bud which is gradually developed, till it assumes the form and takes the place of the missing member. In these cases, however, the process is not in any way generative, and the product of gemmation can in no sense be spoken of as a distinct being (or zoöid).

Another form of gemmation may be exemplified by what takes place in the Foraminifera, one of the classes of the Protozoa. The primitive form of a Foraminifer is simply a little sphere of sarcode, which has the power of secreting from its outer surface a calcareous envelope; and this condition may be permanently retained (as in Lagena). In other cases a process of budding or gemmation takes place, and the primitive mass of sarcode produces from itself, on one side, a second mass exactly similar to the first, which does not detach itself from its parent, but remains permanently connected with it. This second mass repeats the process of gemmation as before, and this goes on—all the segments remaining attached to one another—until a body is produced, which consists of a number of little spheres of sarcode, in organic connection with one another, and surrounded by a shell, often of the most complicated description. In this case, however, the buds produced by the primitive spherule are not only not detached, but they can only remotely be regarded as independent beings. They are, in all respects, identical with the primordial segment, and it is rather a case of 'vegetative' repetition of similar parts.

Another form of gemmation is exhibited in such an organism as the common sea-mat (Flustra), which is a composite organism composed of a multitude of similar beings, each of which inhabits a little chamber, or cell; the whole forming a structure not unlike a sea-weed in appearance. This colony is produced by gemmation from a single primitive being ('polypide'), which throws out buds, each of which repeats the process, apparently almost indefinitely. All the buds remain in contact and connected with one another, but each is, nevertheless, a distinct and independent being, capable of performing all the functions of life. In this case, therefore, each one of the innumerable buds becomes an independent being similar to, though not detached from, the organism which gave it birth. This is an instance of what is called 'continuous gemmation.'

In other cases—as in the common fresh-water polype or Hydra—the buds which are thrown out by the primitive organism become developed into creatures exactly resembling the parent, but, instead of remaining permanently attached, and thus giving rise to a compound organism, they are detached to lead an entirely independent existence. This is a simple instance of what is termed 'discontinuous gemmation.'

The method and results of fission may be regarded as essentially the same as in the case of gemmation. The products of the division of the body of the primitive organism may either remain undetached, when they will give rise to a composite structure (as in many corals), or they may be thrown off and live an independent existence (as in some of the Hydrozoa).

We are now in a position to understand what is meant, strictly speaking, by the term 'individual.' In zoological language, an *individual* is defined as '*equal to the total result of the development of a single ovum.*' Amongst the higher animals there is no difficulty about this, for each ovum gives rise to no more than one single being, which is incapable of repeating itself in any other way than by the production of another ovum; so that an individual is a single animal. It is most important, however, to comprehend that this is not necessarily or always the case. In such an organism as the sea-mat, the ovum gives rise to a primitive polypide which repeats itself by a process of continuous gemmation, until an entire colony is produced, each member of which is independent of its fellows, and is capable of producing ova. In such a case, therefore, the term 'individual' must be applied to the entire colony, since this is the result of the development of a single ovum. The separate beings which compose the colony are technically called 'zoöids.' In like manner, the Hydra which produces fresh and independent Hydræ by discontinuous gemmation, is not an 'individual,' but is a zoöid. Here the zoöids are not permanently united to one another, and the 'individual' Hydra consists really of the primitive Hydra, *plus* all the detached Hydræ to which it gave rise. In this case, therefore, the 'individual' is composed of a number of disconnected and wholly independent beings, all of which are the result of the development of a single ovum. It is to be remembered that both the parent zoöid and the 'produced zoöids' are capable of giving rise to fresh Hydræ by a true generative process. It must also be borne in mind that this production of fresh zoöids by a process of gemmation is not so essentially different to the true sexual process of reproduction as might at first sight appear, since the ovum itself may be regarded merely as a highly specialised bud. In the Hydra, in fact, where the ovum is produced as an external process of the wall of the body, this likeness is extremely striking. The ovarian bud, however, differs from the true gemmæ or buds in its inability to develop itself into an independent organism, unless previously brought into contact with another special generative element. The only exceptions to this statement are in the rare cases of true 'parthenogenesis,' to be subsequently alluded to.

b. Reproduction by Internal Gemmation.—Before considering the phenomena of 'alternate generations,' it will be as well to glance for a moment at a peculiar form of gemmation exhibited by some of the Polyzoa, which is in some respects intermediate between ordinary discontinuous gemmation and alternation of generations. These organisms are nearly allied to the sea-mat, already spoken of, and, like it, can reproduce themselves by continuous gemmation (forming colonies), by a true sexual process, and rarely by fission. In addition to all these methods they can reproduce themselves by the formation of peculiar internal buds, which are called 'stato-blasts.' These buds are developed upon a peculiar cord, which crosses the body-cavity, and is attached at one end to the fundus of the stomach. When mature they drop off from this cord, and lie loose in the cavity of the body, whence they are liberated on the death of the parent organism. When thus liberated, the stato-blast, after a longer or shorter period, ruptures and gives exit to a young Polyzoon, which has essentially the same structure as the adult. It is, however, simple, and has to undergo a process of continuous gemmation, before it can assume the compound form proper to the adult.

As regards the nature of these singular bodies, 'the invariable absence of germinal vesicle and germinal spot, and their never exhibiting the phenomena of yelk-cleavage, independently of the conclusive fact that true ova and ovary occur elsewhere in the same individual, are quite decisive against their being eggs. We must then look upon them as *gemmæ* peculiarly encysted, and destined to remain for a period in a quiescent or pupa-like state.'—(Allman.)

c. Alternation of Generations.—In the case of the Hydra and the sea-mat, which we have considered above, fresh zoöids are produced by a primordial organism by gemmation; the beings thus produced (as well as the parent) being capable not only of repeating the gemmiparous process, but also of producing new individuals by a true generative act. We have now to consider a much more complex series of phenomena, in which the organism which is developed from the primitive ovum produces by gemmation *two* sets of zoöids, one of which is destitute of sexual organs, and is capable of performing no other function than that of nutrition, whilst the other is provided with reproductive organs, and is destined for the perpetuation of the species. In the former case the produced zoöids all resembled each other, and the parent organism which gave rise to them; in the latter case, the produced zoöids are often utterly unlike each other and unlike the parent, since their functions are entirely different.

The simplest form of the process is seen in certain of the Hydroid Polypes, such as Campanularia. The ovum of Campanularia is a free-swimming ciliated body, which, after a short locomotive existence, attaches itself to some submarine object, develops a mouth and tentacles, and commences to produce zoöids like itself by a process of continuous gemmation. These remain permanently attached to one another, with the result that a compound organism is produced, consisting of a number of zoöids, or 'polypites,' organically connected together, but enjoying an independent existence. None of the zoöids, however, are provided with sexual organs; and though there is theoretically no limit to the size which the colony may reach by gemmation, its buds are not detached, and the species would, therefore, die out, unless some special provision were made for its preservation. Besides these nutritive zoöids, however, other buds are produced which differ considerably in appearance from the former, and which have the power of generating the essential elements of reproduction. These generative zoöids derive their nourishment from the materials collected by the nutritive zoöids, but only live until the ova are matured in their interior and liberated, when they disappear. The ova thus produced become free-swimming ciliated bodies, such as the one with which the cycle began.

In this case, therefore, the 'individual' Campanularia consists of a series of nutritive zoöids, collectively called the 'trophosome,' and another series of reproductive zoöids, collectively called the 'gonosome'—the entire series remaining in organic connection.

In other forms nearly allied to Campanularia (such as Coryne) the process advances a step further. In Coryne the generative buds, or zoöids, do not produce the reproductive elements as long as they remain attached to the parent colony; but they require a preliminary period of independent existence. For this purpose they are specially organised, and when sufficiently matured they are detached from the stationary colony. The generative zoöid now appears as an entirely independent being, described as a species of jelly-fish (or Medusa) under the name of Sarsia. It consists of a bell-shaped disc, by means of which it is enabled to swim freely; from the centre of this disc depends a nutritive process, with a mouth and digestive cavity, whereby the organism is able to increase considerably in size. The substance of the disc is penetrated by a complex system of canals, and from its margin hang a series of tentacular processes. After a period of independent locomotive existence, the Medusa attains its full growth, when it develops ova and spermatozoa. By the contact of these embryos are produced; but these, instead of resembling the jelly-fish by which they were immediately generated, proceed to develop themselves into the fixed Hydroid colony by which the Medusa was originally produced.

Still more extraordinary phenomena have been discovered in other Hydrozoa, as in many of the Lucernarida. In these the ovum gives rise (as in Campanularia) to a locomotive ciliated body, which ultimately fixes itself, becomes trumpet-shaped, and develops a mouth and tentacles at its expanded extremity, when it is known as the 'hydra-tuba,' from its resemblance to the fresh-water polype, or Hydra. The hydra-tuba has the power of multiplying itself by gemmation, and it can produce large colonies in this way; but it does not obtain the power of generating the essential elements of reproduction. Under certain circumstances, however, the hydra-tuba enlarges, and, after a series of preliminary changes, divides by transverse fission into a number of segments, each of which becomes detached and swims away. These liberated segments of the little hydra-tuba (it is about half an inch in height) now live as entirely independent beings, which were described by naturalists as distinct animals, and were called Ephyræ. They are provided with a swimming-bell, or 'umbrella,' by means of which they propel themselves through the water, and with a mouth and digestive cavity. They now lead an active life, feeding eagerly, and attaining in some instances a perfectly astonishing size (the Medusoids of some species are several feet in circumference). After a while they develop the essential elements of reproduction, and after the fecundation and liberation of their ova they die. The ova, however, are not developed into the free-swimming, and comparatively gigantic jelly-fish, by which they were immediately produced, but into the minute, fixed, sexless hydra-tuba.

We thus see that a small, sexless zoöid, which is capable of multiplying itself by gemmation, produces by fission several independent locomotive beings, which are capable of nourishing themselves and of performing all the functions of life. In these are produced generative elements, which give rise by their development to the little fixed creature with which the series began.

To the group of phenomena of which the above are examples, the name 'alternation of generations' was applied by Steenstrup; but the name is not an appropriate one, since the process is truly an alternation of generation with gemmation or fission. The only generative act takes place in the reproductive zoöid, and the production of this from the nutritive zoöid is a process of gemmation or fission, and not a process of generation. The 'individual,' in fact, in all these cases must be looked upon as a double being composed of two factors, both of which lead more or less completely independent lives, the one being devoted to nutrition, the other to reproduction. The generative being, however, is in many cases not at first able to mature the sexual elements, and is, therefore, provided with the means necessary for its growth and nourishment as an independent organism. It must, also, be remembered that the nutritive half of the 'individual' is usually, and the generative half sometimes, *compound*, that is to say, composed of a number of zoöids produced by continuous gemmation; so that the zoological individual in these cases becomes an extremely complex being.

These phenomena of so-called 'alternation of generations,' or 'meta-genesis,' occur in their most striking form amongst the Hydrozoa; but they occur also amongst many of the intestinal worms (Entozoa), and amongst some of the Tunicata (Molluscoida).

d. Parthenogenesis.—'Parthenogenesis' is the term employed to designate certain singular phenomena, resulting in the production of new individuals by virgin females without the intervention of a male. By Professor Owen, who first employed the term, parthenogenesis is applied also to the processes of gemmation and fission, as exhibited in sexless beings or in virgin females; but it seems best to consider these phenomena separately. Strictly, the term parthenogenesis ought to be confined to the production of new individuals from virgin females by means of *ova*, which are enabled to develop themselves without the contact of the male element. The difficulty in this definition is found in framing an exact definition of an ovum, such as will distinguish it from an internal gemma or bud. No body, however, should be called an 'ovum' which does not exhibit a germinal vesicle and germinal spot, and which does not exhibit the phenomenon known as segmentation of the yelk. Moreover, ova are almost invariably produced by a special organ, or ovary.

As examples of parthenogenesis we may take what occurs in plant-lice (Aphides) and in the honey-bee; but it will be seen that in neither of these cases are the phenomena so unequivocal, or so well ascertained, as to justify a positive assertion that they are truly referable to parthenogenesis in the above restricted sense of the term.

The Aphides, or plant-lice, which are so commonly found parasitic upon plants, are seen towards the close of autumn to consist of male and female individuals. By the sexual union of these true ova are produced, which remain dormant through the winter. At the approach of spring these ova are hatched; but, instead of giving birth to a number of males and females, all the young are of one kind, variously regarded as neuters, virgin females, or hermaphrodites. Whatever their true nature may be, these individuals produce *viviparously* a brood of young which resemble themselves; and this second generation, in like manner, produces a third, and so the process may be repeated, for as many as ten or more generations, throughout the summer. When the autumn comes on, however, the viviparous Aphides produce—in exactly the same manner—a final brood; but this, instead of being composed entirely of similar individuals, is made up of males and females. Sexual union now takes place, and ova are produced and fecundated in the ordinary manner.

The bodies from which the young of the viviparous Aphides are produced are variously regarded as internal buds, as 'pseudova' (i.e. as bodies intermediate between buds and ova), and as true ova.

Without entering into details, it is obvious that there is only one explanation of these phenomena, which will justify us in regarding the case of the viviparous Aphides as one of true parthenogenesis, as above defined. If, namely, the spring broods are true females, and the bodies which they produce in their interior are true ova, then the case is one of genuine parthenogenesis, for there are certainly no males. The case might still be called one of parthenogenesis, even though the bodies from which these broods are produced be regarded as internal buds, or as 'pseudova;' for a true ovum is essentially a bud. If, however, Balbiani be right, and the viviparous Aphides are really hermaphrodite, then, of course, the phenomena are of a much less abnormal character.

In the second case of alleged parthenogenesis which we are about to examine, namely, in the honey-bee, the phenomena which have been described cannot be said to be wholly free from doubt. A hive of bees consists of three classes of individuals—1. A 'queen,' or fertile female; 2. The 'workers,' which form the bulk of the community, and are really undeveloped or sterile females; and 3. The 'drones,' or males, which are only produced at certain times of the year. We have here three distinct sets of beings, all of which proceed from a single fertile individual, and the question arises, in what manner are the differences between these produced? At a certain period of the year the queen leaves the hive, accompanied by the drones (or males), and takes what is known as her 'nuptial flight' through the air. In this flight she is impregnated by the males, and it is immaterial whether this act occurs once in the life of the queen, or several times, as asserted by some. Be this as it may, the queen, in virtue of this single impregnation, is enabled to produce fresh individuals for a lengthened period, the semen of the males being stored up in a receptacle, which communicates by a tube with the oviduct, from which it can be shut off at will. The ova which are to produce workers (undeveloped females) and queens (fertile females) are fertilised on their passage through the oviduct, the semen being allowed to escape into the oviduct for this purpose. The subsequent development of these fecundated ova into workers or queens depends entirely upon the form of the cell into which the ovum is placed, and upon the nature of the food which is supplied to the larva. So far there is no doubt as to the nature of the phenomena which are observed. It is asserted, however, by Dzierzon and Siebold, that the males or drones are produced by the queen from ova which she does not allow to come into contact with the semen as they pass through the oviduct. This assertion is supported by the fact that if the communication between the receptacle for the semen and the oviduct be cut off, the queen will produce nothing but males. Also, in crosses between the common honey-bee and the Ligurian bee, the queens and workers alone exhibit any intermediate characters between the two forms, the drones presenting the unmixed character of the queen by whom they were produced.

If these observations are to be accepted as established, then the drones are produced by a true process of parthenogenesis; but some observers maintain, that the development of any given ovum into a drone is really due—as in the case of the queens and workers—to the special circumstances under which the larva is brought up.

There are various other cases in which parthenogenesis is said to occur, but the above will suffice to indicate the general character of the phenomena in question. The *theories* of parthenogenesis appear to be too complex to be introduced here, and there is the less to regret in their omission, as naturalists have not yet definitely adopted any one explanation of the phenomena to the exclusion of the rest.

First Law of Quatrefages.—From the phenomena of asexual reproduction in all its forms, M. de Quatrefages has deduced the following generalisation:—

'The formation of new individuals may take place, in some instances, by gemmation from, or division of, the parent-being; but this process is an exhaustive one, and cannot be carried out indefinitely; when, therefore, it is necessary to insure the continuance of the species, the sexes must present themselves, and the germ and sperm must be allowed to come in contact with one another.'

It should be added that the act of sexual reproduction, though it insures the perpetuation of the *species*, is very destructive to the life of the *individual*. The formation of the essential elements of reproduction appears to be one of the highest physiological acts of which the organism is capable, and it is attended with a corresponding strain upon the vital energies. In no case is this more strikingly exhibited than in the majority of insects, which pass the greater portion of their existence in a sexually immature condition, and die almost immediately after they have become sexually perfect, and have consummated the act whereby the perpetuation of the species is secured.

11. DEVELOPMENT, TRANSFORMATION, AND METAMORPHOSIS.

Development is the general term applied to all those changes which a germ undergoes before it assumes the characters of the perfect individual; and the chief differences which are observed in the process as it occurs in different animals consist simply in the extent to which these changes are external and visible, or are more or less completely concealed from view. For these differences the terms 'transformation' and 'metamorphosis' are employed; but they must be regarded as essentially nothing more than variations of development.

Transformation is the term employed by Quatrefages to designate 'the series of changes which every germ undergoes in reaching the embryonic condition; those which we observe in every creature still within the egg; those, finally, which the species born in an imperfectly developed state present in the course of their external life.'

Metamorphosis is defined by the same author as including the alterations which are 'undergone after exclusion from the egg, and which alter extensively the general form and mode of life of the individual.'

Though by no means faultless, these terms are sufficiently convenient, if it be remembered that they are merely modifications of development, and express differences of degree and not of kind. An insect, such as a butterfly, is the best illustration of what is meant by these terms. All the changes which are undergone by a butterfly in passing from the fecundated ovum to the condition of an imago, or perfect insect, constitute its *development*. The egg which is laid by a butterfly undergoes a series of changes, which eventuate in its giving birth to a caterpillar, these preliminary changes constituting its *transformation*. The caterpillar grows rapidly, and after several changes of skin becomes quiescent, when it is known as a 'chrysalis.' It remains for a longer or shorter time in this quiescent and apparently dead condition, during which period developmental changes are going on rapidly in its interior. Finally, the chrysalis ruptures, and there escapes from it the perfect winged insect. To these changes the term *metamorphosis* is rightly applied. These changes, however, do not differ in kind from the changes undergone by a mammal; the difference being that in the case of a mammal the ovum is retained within the body of the parent, where it undergoes the necessary developmental changes, so that at birth it has little to do but grow, in order to be converted into the adult animal.

From these considerations we arrive at the second law laid down by Quatrefages :—'Those creatures whose ova—owing to an insufficient supply of nutritious contents and an incapacity on the part of the mother to provide for their complete development within her own substance—are rapidly hatched, give birth to imperfect offspring, which, in proceeding to their definitive characters, undergo several alterations in structure and form, known as metamorphoses.'

Retrograde Development.—Ordinarily speaking, the course of development is an ascending one, and the adult is more highly organised than the young; but there are cases in which there is an apparent reversal of this law, and the adult is to all appearance a degraded form when compared with the embryo. This phenomenon is known as 'retrograde,' or 'recurrent' development, and well marked instances are found amongst the Cirripedia and Lerneæ, both of which belong to the Crustacea.

Thus, in the Cirripedes (acorn-shells, &c.) and in the parasitic Lerneæ the embryo is free-swimming and provided with organs of vision and sensation, being in most respects similar to the permanent condition of certain other Crustacea, such as the Cypris (Ostracoda). The adult, however, in both cases, is degraded into a more or less completely sedentary animal, more or less entirely deprived of organs of sense, and leading an almost vegetative life. As a compensation, reproductive organs are developed in the adult, and it is in this respect superior to the locomotive, but sexless, larva.

12. Spontaneous Generation.

Spontaneous or Equivocal generation is the term applied to the alleged production of living beings without the pre-existence of germs of any kind, and therefore without the pre-existence of parent organisms. The question is one which has been long and closely disputed, and is far from being settled; so that it will be sufficient to indicate the facts upon which the theory rests.

If an animal or vegetable substance be soaked in hot or cold water, so as to make an organic infusion, and if this infusion be exposed for a sufficient length of time to the air, the following series of changes is usually observed.

1. At the end of a longer or shorter time, there forms upon the surface of the infusion a thin scum, or pellicle, which, when examined microscopically, is found to consist of an incalculable number of extremely minute molecules.

2. In the next stage these molecules appear, many of them, to have melted together in twos and threes to form short filaments, called 'bacteria,' which become longer by the apposition of fresh molecules at their extremities, or by uniting with one another, when they are termed 'vibriones.' Both the bacteria and the vibrios now exhibit a vibratile or serpentine movement through the surrounding fluid.

3. After a varying period, the bacteria and vibrios become motionless, and disintegrate so as to produce again a finely molecular pellicle.

4. Little spherical bodies now appear, each of which is provided with a vibratile cilium with which it moves actively through the infusion. (Monas lens.)

5. Varied forms of ciliated Infusoria—some which possess a mouth and are otherwise highly organised—make their appearance in the fluid.

The above is the general sequence of the phenomena which have been observed, and the following are the two theories which have been advanced to account for them.

a. By the advocates of spontaneous generation, or 'Heterogeny,' it is affirmed that the Infusoria, which finally appear in the infusion, are produced spontaneously out of the molecular pellicle, the molecules of which are also of spontaneous origin, and are not derived from any pre-existing germs.

b. By the 'panspermists,' or the opponents of spontaneous generation, it is alleged, on the other hand, that the production of Bacteria, Vibrios, Monads, and Infusoria, in organic infusions is due simply to the fact that the atmosphere, and probably the fluid itself, is charged with innumerable germs—too minute, perhaps, to be always detectable by the microscope—which, obtaining access to the fluid, and finding there favourable conditions, are developed into living beings.

A large number of elaborate experiments have been carried out to prove that atmospheric air is absolutely necessary for the production of these living beings, and that if the air be properly purified by passage through destructive chemical reagents, no such organisms will be produced, provided that the infusion have been previously boiled. As the results of all these experimental trials have hitherto proved more or less contradictory, it is unnecessary to enter into the question further, and it will be sufficient to indicate the following general considerations:—

a. The primary molecules which appear in the fluid are extremely minute, and if they are developed from germs, these may be so small as to elude any power of the microscope yet known to us. As they subsequently coalesce to form the bacteria and vibrios, and as there can be little dispute as to these being truly living organisms, we are obliged to believe that they must have had *some* definite origin. It appears, however, to be hardly philosophical to assume that they form themselves out of the inorganic materials of the infusion; since this implies the sudden appearance, or creation, of new force, for which there seems to be no means of accounting.

b. The nature of the vibrios and bacteria must be looked upon as quite uncertain. To say the least of it, they are quite as likely to be plants as animals; and the most probable hypothesis would place them near the filamentous Confervæ.

c. What has been said above with regard to the origin of the bacteria and vibrios applies equally to the origin of the Monads, which appear in the infusion subsequently to the death of the vibrios.

d. These Monads, as shown by recent researches, are probably to be looked upon as the embryonic, or larval, forms of the higher Infusoria which succeed them.

e. Many of the Infusoria, which finally appear, are of a comparatively high grade of organisation, being certainly the highest of the Protozoa, and being placed by some competent observers in the neighbourhood of the Trematode Worms (Annuloida). It is, therefore, very unlikely that these should be generated spontaneously; since if this ever occurs, it is reasonable to suppose that the creatures thus produced will be of the lowest possible organisation (such as the Gregarinidæ for example), and will be far below the Infusoria in point of structure.

f. The reproductive process in many of these same Infusoria is perfectly well known, and it consists either in a true sexual process, for which proper organs are provided (as in Paramœcium), or in a process of gemmation or fission. It is, therefore, contrary to analogy to suppose that they should be generated in the manner maintained by the heterogenists, since this mode of reproduction would appear to be superfluous.

h. In the absence of any direct proof to the contrary, it is safer to adopt an explanation of the observed phenomena which does not have recourse to laws with which we are as yet unacquainted. Thus, it is not at variance with any known law to suppose that the primary molecules are the result of the development of germs which find in the organic infusion a suitable *nidus*; that these primary molecules and the vibrios which they produce are referable to the Protophyta, and should probably be placed near the filamentous Confervæ; that by the death of these vegetable organisms the fluid is prepared for the reception and development of the germs of the Protozoa, for which the former serve as *pabulum*; and that many of the forms which are observed are the larval stages of the higher Infusoria.

13. Origin of Species.

It is impossible here to do more than merely indicate in the briefest manner the two fundamental ideas which are at the bottom of all the various theories as to the origin of species. The opinions of scientific men are still divided upon this subject, and it will be sufficient to give an outline of the two leading theories, without adducing any of the reasoning upon which they are based.

I. *Doctrine of Special Creation.*—On this doctrine of the origin of species it is believed that species are immutable productions, each of which has been specially created at some point within the area in which we now find it, to meet the external conditions there prevailing, subsequently spreading from this spot as far as the conditions of life were suitable for it.

II. *Doctrine of Development.*—On the other hand, it is believed that species are not permanent and immutable, but that they 'undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms.' (Darwin.)

On Lamarck's theory of the development of species, the means of modification were ascribed to the action of external physical agencies, the inter-breeding of already existing forms, and the effects of habit.

The doctrine of the development of species by variation and natural selection—propounded by Darwin, and commonly known as the Darwinian theory—is based upon the following fundamental propositions.

1. The progeny of all species of animals and plants exhibit variations amongst themselves in all parts of their organisation; no two individuals being exactly alike. In other words, in every species the individuals tend by variation to diverge from the parent-type, in some particular or other.

2. These variations can be transmitted to future generations under certain definite and discoverable laws of inheritance.

3. By artificial selection and breeding from individuals possessing any particular variation, man, in successive generations, can produce a breed in which the variation is permanent; the races thus produced being often as widely different as are distinct species of wild animals.

4. The world in which all living beings are placed is one not absolutely unchanging, but is liable to subject them to very varying conditions.

5. All animals and plants give rise to more numerous young than can by any possibility be preserved.

6. As these young are none of them exactly alike, a process of 'Natural Selection' will ensue, whereby those individuals which possess any variation favourable to the peculiarities of the life of the species, will be preserved. Those individuals which do not possess such a favourable variation will be placed at a disadvantage in the 'struggle for existence,' and will tend to be gradually exterminated.

7. Other conditions remaining the same, the individuals which survive in the struggle for existence will transmit the variations, to which their preservation is due, to future generations.

8. By a repetition of this process 'varieties' are first established; these become permanent, and 'races' are produced; finally, in the lapse of time, the differences become sufficiently great to constitute distinct species.

14. Distribution.

Under this head come all the facts which are concerned with the external or objective relations of animals; that is to say, their relations to the external conditions in which they are placed.

The *geographical* distribution of animals is concerned with the determination of the areas within which every species of animal is at the present day confined. Some species are found almost everywhere, when they are said to be 'cosmopolitan;' but as a rule each species is confined to a limited and definite area.

The *vertical* or *bathymetrical* distribution of animals relates to the limits of depth within which each marine species of animals is confined. As a rule it is found that each species has its own definite bathymetrical zone, and that its existence is difficult or impossible at depths greater or less than those comprised by that zone. Generalising on a large number of facts, naturalists have been able to lay down and name certain definite zones, each of which has its own special fauna.

The four following zones are those generally accepted:—

1. The Littoral zone, or the tract between tide-marks.
2. The Laminarian zone, from low water to 15 fathoms.
3. The Coralline zone, from 15 to 50 fathoms.
4. The deep-sea Coral zone, 50 to 100 fathoms or more.

In addition to the preceding forms of distribution, the zoologist has to investigate the condition and nature of animal life during past epochs in the history of the world.

The laws of *distribution in time*, however, are, from the nature of the case, less perfectly known than are the laws of lateral or vertical distribution, since these latter concern beings which we are able to examine directly. The following are the chief facts which it is necessary for the student to bear in mind.

1. The rocks which compose the crust of the earth have been formed at successive periods; and may be roughly divided into aqueous or sedimentary rocks and igneous rocks.

2. The igneous rocks are produced by the agency of heat, are mostly *unstratified* (i. e. are not deposited in distinct layers or *strata*), and, with few exceptions, are destitute of any traces of past life.

3. The sedimentary or aqueous rocks owe their origin to the action of water, are *stratified* (i. e. consist of separate layers or *strata*), and mostly exhibit 'fossils'—that is to say, the remains or traces of animals or plants which were in existence at the time when the rocks were deposited.

4. The series of aqueous rocks is capable of being divided into a number of definite groups of strata, which are technically called 'formations.'

5. Each of these definite rock-groups, or 'formations,' is characterised by the occurrence of an assemblage of fossil remains more or less peculiar and confined to itself.

6. The majority of these fossil forms are 'extinct;' that is to say, they do not admit of being referred to any species at present existing.

7. No fossil, however, is known, which cannot be referred to one or other of the primary subdivisions of the Animal Kingdom, which are represented at the present day.

8. When a species has once died out it never reappears.

9. The older the formation, the greater is the divergence between its fossils and the animals and plants now existing on the globe.

10. All the known formations are divided into three great groups, termed respectively Palæozoic or Primary, Mesozoic or Secondary, and Kainozoic, or Tertiary.

The Palæozoic, or Ancient-life, period is the oldest, and is characterised by the marked divergence of the life of the period from all existing forms.

In the Mesozoic, or Middle-life, period the general *facies* of the fossils approaches more nearly to that of our existing fauna and flora; but—with very few exceptions—the characteristic fossils are all specifically distinct from all existing forms.

In the Kainozoic, or New-life, period, the approximation of the fossil remains to existing living beings is still closer, and some of the forms are now specifically identical with recent species; the number of these increasing rapidly as we ascend from the lowest Kainozoic deposit to the Recent Period.

Subjoined is a table giving the more important subdivisions of the three great geological periods, commencing with the oldest rocks and ascending to the present day.

I. Palæozoic or Primary Rocks.

1. Laurentian. (Lower and Upper.)
2. Cambrian. (Lower and Upper, with Huronian Rocks?)
3. Silurian. (Lower and Upper.)
4. Devonian, or Old Red Sandstone. (Lower, Middle and Upper.)
5. Carboniferous. (Mountain-limestone, Millstone Grit and Coal-measures.)
6. Permian. (=the lower portion of the New Red Sandstone.)

II. Mesozoic or Secondary Rocks.

7. Triassic Rocks. (Bunter Sandstein, or Lower Trias; Muschelkalk, or Middle Trias; Keuper, or Upper Trias.)
8. Jurassic Rocks. (Lias, Inferior Oolite, Great Oolite, Oxford Clay, Coral Rag, Kimmeridge Clay, Portland Stone, Purbeck beds.)
9. Cretaceous Rocks. (Wealden, Lower Greensand, Gault, Upper Greensand, White Chalk, Maestricht beds.)

III. Kainozoic or Tertiary Rocks.

10. Eocene. (Lower, Middle, and Upper.)
11. Miocene. (Lower and Upper.)
12. Pliocene. (Older Pliocene and Newer Pliocene.)
13. Post-tertiary. (Post-pliocene, and Recent.)

PROTOZOA.

CHAPTER I.

1. General Characters of the Protozoa. 2. Classification. 3. Gregarinidæ.

1. *General Characters.*—The sub-kingdom *Protozoa*, as the name implies, includes the most lowly organised members of the animal kingdom. From this circumstance it is difficult, if not impossible, to give an exhaustive definition, and the following is, perhaps, as exact as the present state of our knowledge will allow.

The *Protozoa* may be defined as *animals, generally of minute size, composed of a nearly structureless jelly-like substance (termed 'sarcode'), showing no composition out of definite parts or segments, having no definite body-cavity, presenting no traces of a nervous system, and having either no differentiated alimentary apparatus, or but a very rudimentary one.*

The *Protozoa* are almost exclusively aquatic in their habits, and are mostly very minute, though they sometimes form colonies of considerable size. They are comprised of a more or less contractile, jelly-like substance, called 'sarcode' or 'animal protoplasm,' which is semi-fluid in consistence, and is composed of an albuminous base with oil-globules scattered through it. Granules are generally developed in the sarcode, and in many cases there is a definite internal solid particle, termed the 'nucleus.'

In no *Protozoon* are any traces known of anything like the nervous and vascular arrangements which are found in animals of a higher grade. A nervous system is universally and entirely absent, and the sole circulatory apparatus consists in certain clear spaces called 'contractile vesicles,' which are found in some species, and which doubtfully perform the functions of a heart. A distinct alimentary cavity is present in the higher *Protozoa*, but in many there is none, and in all the digestive apparatus is of the simplest character. Organs of generation, or at any rate differentiated portions of the body which act as these, are sometimes present; but in many cases true sexual reproduction has not hitherto been shown to exist.

The 'sarcode' which forms such a distinctive feature in all the *Protozoa*, is a structureless albuminous substance, not possessing 'permanent distinction or separation of parts,' but nevertheless displaying all 'the essential properties and characters of vitality,' being capable of assimilation and excretion, of irritability, and of the power of contraction so as to produce movements, strictly analogous, in many cases, to the muscular movements of the higher animals. In some, too, the sarcode possesses the power of producing an external case or envelope, usually of carbonate of lime or flint, and often of a very complicated and mathematically regular structure.

The most characteristic organs of locomotion amongst the *Protozoa* are known as 'pseudopodia,' and consist simply of prolongations of the sarcodic substance of the body, which can usually be emitted from the greater portion of the general surface of the body, and are capable of being again retracted and of fusing completely with the body-substance.

2. *Classification of the Protozoa.* The sub-kingdom *Protozoa* is divided into three classes, viz. the *Gregarinidæ*, the *Rhizopoda*, and the *Infusoria*. In the Infusoria only is a mouth present, and hence these are sometimes spoken of as the '*Stomatode*' *Protozoa*, whilst the two former classes collectively constitute the '*Astomata*.'

The following is a tabular view of the divisions of the *Protozoa*:—

Class I. GREGARINIDÆ.

Class II. RHIZOPODA.
Order 1. *Amœbea*.
„ 2. *Foraminifera*.
„ 3. *Radiolaria*.
„ 4. *Spongida*.

Class III. INFUSORIA.
Order 1. *Suctoria*.
„ 2. *Ciliata*.
„ 3. *Flagellata*.

3. CLASS I. GREGARINIDÆ.—The *Gregarinidæ* may be defined as *parasitic Protozoa, which are destitute of a mouth and do not possess the power of emitting 'pseudopodia.'* They constitute the lowest class of the *Protozoa*, and comprise certain microscopic animals which are parasitic in the alimentary canal of both invertebrate and vertebrate animals. They have, however, a special liking for the intestines of certain insects, being commonly found abundantly in the cockroach.

Nothing anatomically could be more simple than the structure of a *Gregarina*, since it is almost exactly that of the unimpregnated ovum (*fig.* 1 *a*). An adult Gregarina, in fact, may be said to be a single cell, consisting of an ill-defined membranous envelope filled with a more or less granular sarcode, which contains in its interior a vesicular nucleus, this in turn enclosing a solid particle, or nucleolus. In some the body exhibits an approach to a more complex structure by the presence of internal septa; but it is doubtful whether this appearance may not be due to the apposition and fusion of two separate individuals. In others one end of the body is furnished with uncinate processes, very similar in appearance to the hooked 'head' of the common tape-worm (*Tænia solium*). Essentially, however, the structure of all appears to be the same. No differentiated organs of any kind beyond the nucleus and nucleolus exist, and both assimilation and excretion must be performed simply by the general surface of the body. The body is, nevertheless, contractile, and slow movements can apparently be effected.

In spite of their exceedingly simple structure, the following very interesting reproductive phenomena have been observed,

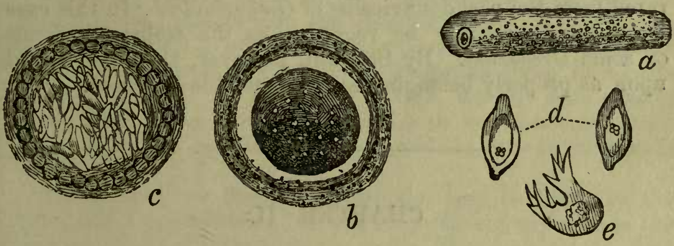


Fig. 1.—Gregarina of the earth-worm. *a.* Adult *Gregarina.* *b.* The same encysted. *c.* With the contents divided into pseudonavicellæ. *d.* Free pseudonavicellæ. *e.* Free amœbiform contents of the pseudonavicellæ. (After Lieberkühn.)

sometimes in a single *Gregarina* without apparent cause, sometimes as the result of the apposition and coalescence of two individuals—the exact nature of the process being in either case obscure. The *Gregarina*—or it may be two individuals which have come into contact and adhered together—assumes a globular form, becomes motionless, and develops round itself a structureless envelope or cyst, when it is said to be 'encysted' (*fig.* 1 *b*). The central nucleus then disappears, apparently by dissolution, whereupon the granular contents of the cyst break up into a number of little rounded masses, which gradually elongate and become lanceolate, when they are termed 'pseudonavicellæ' (or 'pseudonaviculæ') (*fig.* 1 *c*). The next step in the process consists in the liberation of the pseudonavicellæ which escape by the rupture of the enclosing cyst (*fig.* 1 *d*). If they now find a congenial habitat, they give origin to little albuminous or sarcodic masses, which exhibit lively movements, and are endowed with the power of throwing out and retracting little processes of the body which closely resemble the 'pseudopodia' of the *Rhizopoda*; so that the pseudonavicella in this condition is very similar to an adult *Amœba* (*fig.* 1 *e*). Finally these amœbiform bodies are developed into adult *Gregarinæ*. It will be seen from the above that the formation of the pseudonavicellæ out of the granular contents of the body, subsequent to the disappearance of the nucleus, presents some analogy to the segmentation of the impregnated ovum which follows upon the dissolution of the germinal vesicle.

PSOROSPERMIÆ.—There occur as parasites on and within the bodies of fishes certain vesicular, usually caudate, bodies, termed *Psorospermiæ*, the exact nature of which is very problematical. According to Lieberkühn they occasionally give origin to amœbiform bodies, similar to those which are liberated from the pseudonavicellæ of *Gregarinidæ*. In this case they should probably be regarded as the embryonic forms of some *Gregarina*. By Balbiani, however, they are looked upon as properly belonging to the vegetable kingdom.

CHAPTER II.

RHIZOPODA.

GENERAL CHARACTERS OF THE RHIZOPODA. — The *Rhizopoda* may be defined as *Protozoa, which are destitute of a mouth, are simple or compound, and possess the power of emitting 'pseudopodia.'* They are mostly small, but some of the composite forms, such as the sponges, may attain a very considerable size. Structurally a typical Rhizopod — as an *Amœba*—is composed of almost structureless sarcode, without any organs appropriated to the function of digestion, and possessing the power of throwing out processes of its substance so as to constitute adventitious limbs. These are termed 'pseudopodia,' or false feet, and are usually protrusible at will from different parts of the body, into the substance of which they again melt when they are retracted. They are merely filaments of sarcode, sometimes very delicate, and of considerable length, at other times more like finger-shaped processes; and they are somewhat analogous to the little processes which are occasionally thrown out by the white corpuscles of the blood and by pus-cells. Indeed, it has been remarked by Huxley that an *Amœba* is structurally 'a mere colourless blood-corpuscle, leading an independent life.'

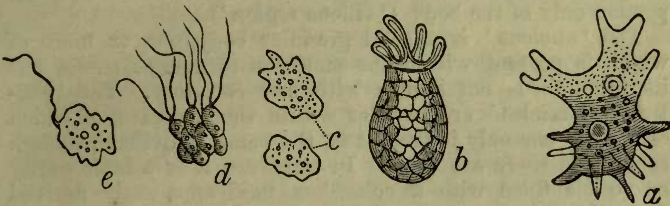


Fig. 2.—Morphology of Rhizopoda. *a. Amœba radiosa*, showing the pseudopodia, contractile vesicle, and nucleus. *b. Difflugia*, with the pseudopodia protruded from the anterior end of the carapace. *c.* Individual sponge-particles, or 'sarcoids.' *d.* Ciliated sponge-particles of *Grantia*, showing the resemblance to flagellate Infusorians. *e.* Mono-ciliated sarcoid of *Spongilla* (after Carter).

The class *Rhizopoda* is divided into four orders, viz. the *Amœbea*, the *Foraminifera*, the *Radiolaria*, and the *Spongida*, of which the last is occasionally considered as a separate class.

ORDER I. AMŒBEA.—This order comprises those *Rhizopoda which are, with one or two exceptions, naked, have usually short, blunt, lobose pseudopodia, which do not anastomose with one another, and contain a 'nucleus,' and one or more 'contractile vesicles.'*

The *Amœba*, or Proteus-animalcule, may be taken as the type, and a description of it will be sufficient to indicate the leading points of interest in the order. The *Amœba* (*fig.* 2 *a*) is a microscopic animalcule which inhabits fresh water, and is composed of gelatinous sarcode, which admits of a separation into two distinct layers:—an outer transparent layer, termed the 'ectosarc,' and an inner, more fluid and mobile, molecular layer, called the 'endosarc.' The 'ectosarc' is highly extensile and contractile, and is the layer of which the 'pseudopodia' are mainly composed; whilst the 'endosarc' contains the only organs possessed by the animal, viz. the 'nucleus' and 'contractile vesicle' or vesicles, along with certain fortuitous cavities termed 'food-vacuoles.'

It is believed by some that the ectosarc is surrounded by a colourless and structureless investing membrane, or cuticle; but this is denied by others. Be this as it may, there is no oral cavity, and the food is merely taken into the interior of the body by a process of intussusception; any portion of the surface being chosen for this purpose, and acting as an extemporaneous mouth. When the particle of food has been received into the body, the aperture by which it was admitted again closes up, and the discharge of solid excreta is effected in an exactly similar manner. In this case, however, the area of the general surface within which an anus may be extemporised, appears to be more restricted and to comprise a portion only of the body ('villous region').

The 'nucleus' is a solid granular body, one or more of which is present within the endosarc of every *Amœba*, but its function is not known with any certainty. The 'contractile vesicles' are cavities within the endosarc, of which ordinarily one only is present in the same individual, though sometimes there are more. In structure it is a little cavity or vesicle filled with a colourless fluid apparently derived from the digestion, and exhibiting rhythmical movements of contraction (*systole*) and dilatation (*diastole*). In some cases radiating tubes are said to have been seen proceeding from the vesicle at the moment of contraction. Regarded functionally, the contractile vesicle must be looked upon as a circulatory organ, and it offers therefore the most rudimentary form of a vascular system with which we are as yet acquainted.

Besides these proper organs, the endosarc usually contains clear spaces, which are called 'vacuoles,' or, more properly, 'food-vacuoles.' These spaces are of a merely temporary character, and are simply produced by the presence of particles of food, usually with a little water taken into the body along with the food.

There are no traces of any organs of sense, or of a nervous system, or, indeed, of any other organs in addition to those already described. Locomotion is effected, with moderate activity, but in an irregular manner, by means of the blunt, finger-shaped processes of sarcode, or 'pseudopodia,' which can be protruded at will from any part of the body, and can be again retracted within it. The pseudopodia also serve as prehensile organs; but they do not interlace and form a network as in many others of the *Rhizopoda*.

As regards the reproductive process in the *Amœba*, no differentiated sexual organs have hitherto been discovered, and the true sexual form of the process is therefore unknown. Fresh individuals, however, may be produced in three ways:—*Firstly*, by simple fission, the animal dividing into two parts, each of which becomes an independent organism. *Secondly*, by the detachment of a single pseudopodium, which becomes developed into a fresh *Amœba*. *Thirdly*, by the production of little spherical masses of sarcode which may be derived from the nucleus by fission, or may be produced by a segmentation of the endosarc, the animal having previously become torpid, and the nucleus and contractile vesicle having disappeared. These little masses, however produced, develop themselves when liberated into ordinary *Amœbæ*. This last method of reproduction is obviously very closely analogous to the production of 'pseudonavicellæ' in an encysted *Gregarina*.

The remaining members of the *Amœbea* are constructed more or less closely after the type of the *Amœba* itself. In the nearly allied *Difflugia* the sarcode forming the body of the animal is invested with a membranous envelope or 'carapace,' strengthened by grains of sand and other adventitious solid particles, and having a single aperture at one extremity, through which the pseudopodia are protruded (*fig.* 2 *b*). In *Arcella* there is a discoid or bason-shaped carapace, secreted by the animal itself, and likewise possessing but a single pseudopodial aperture, placed in this case on the flat surface of the body.

In *Pamphagus* there is no carapace, but the pseudopodia are nevertheless protrusible from one extremity only of the body, the remainder of the surface appearing to be of too resistant a consistence to allow of this. The common *sun-animalcule* (*Actinophrys sol*) is another well-known Rhizopod which is usually placed in this order (*fig.* 3). It consists of a spherical mass of sarcode, about 1–1,300 of an inch in diameter, and usually covered with long, radiating, filamentous pseudopodia, which are much less mobile than in the case of the *Amœba*. The division of the substance of the body into ectosarc and endosarc is tolerably evident, and the latter contains numerous granules and vacuoles. The pseudopodia are derived from the ectosarc alone, the endosarc not passing into them, and they exhibit a circulation of granules along their edges, though this is not nearly so marked a feature as in the case of the *Foraminifera*. A nucleus and contractile vesicle are also present.

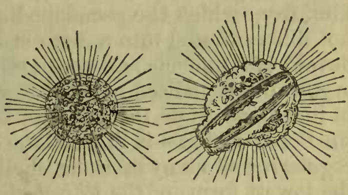


Fig. 3.—*Actinophrys sol:* showing the radiating pseudopodia. One specimen has swallowed a Diatom.

The *Amœbea* may be divided into two sub-orders: 1. *Amœbina*, including those forms which have the body naked; and 2. *Arcellina*, comprising those in which the body is protected by a carapace.

CHAPTER III.

FORAMINIFERA.

THE *Foraminifera* may be defined as *Rhizopoda in which the body is protected by a shell, or 'test,' usually composed of carbonate of lime; there is no distinct separation of the sarcode of the body into ectosarc and endosarc, and the nucleus and contractile vesicle are both absent. The pseudopodia are long and filamentous and interlace with one another to form a net-work.*

The *Foraminifera* are specially characterised by the possession of a 'test' or external shell, which is usually composed of carbonate of lime, but is sometimes membranous. (If *Lieberkühnia* is to be regarded as a *Foraminifer*, the possession of a test cannot be looked upon as essential, since this animalcule is naked.) The test is usually composed of an aggregation of chambers or 'loculi,' and its walls are usually pierced by numerous pores or 'foramina' through which the pseudopodia are protruded; the place of these being in some forms supplied by the large size of the terminal, or '*oral*,' aperture of the shell.

As regards the soft parts of the *Foraminifera*, the body is composed of extensile and contractile sarcode—usually reddish or yellowish in colour—which not only fills the interior of the shell, but generally invests its outer surface also with a thin film, from which the pseudopodia are emitted. The sarcode is not differentiated into a distinct ectosarc and endosarc, and is devoid of a nucleus and contractile vesicle, and, indeed, of any organs or specialised parts of any kind. From this uniformity in its composition there seems some reason to conclude that the Foraminifera—in spite of the complexity and mathematical regularity of many of their shells—should be looked upon as the lowest forms of the *Rhizopoda*, or even of the *Protozoa.*

The pseudopodia in all the *Foraminifera* are filamentous and protrusible to a great length, and they possess the singular property of uniting together in various directions so as to form a kind of net-work, like an 'animated spider's-web.' (Hence the name *Reticularia* applied to the order by Dr. Carpenter.) This property, however, is not peculiar to members of this order, but is seen also in *Actinophrys* and in the *Thalassicollida*, though to a less extent. Further, throughout the entire net-work formed by the inosculating pseudopodia there is a constant circulation of granules in different directions. This singular phenomenon is in many respects analogous to the circulation of granules which is seen in many vegetable cells, and it is believed by Dr. Carpenter that 'the conditions of the two sets of phenomena are essentially the same.'

The shells of *Foraminifera* may be classed in three divisions, termed respectively the 'porcellanous,' the 'hyaline' or 'vitreous,' and the 'arenaceous.' The porcellanous shell is quite homogeneous in its composition, is opaque-white when seen by reflected light, and is not perforated by pseudopodial foramina. In these forms (e.g. *Miliola*) the pseudopodia are emitted solely from the mouth of the last-formed segment of the shell. The vitreous shell is transparent and glassy in texture, and its walls are perforated by numerous pseudopodial apertures. The arenaceous shell is properly speaking not a true 'test,' since it is simply composed of particles of sand united together by some unknown cement. Its walls may or may not be traversed by pseudopodial foramina.

As regards the form of the shell, the *Foraminifera* may be conveniently, though arbitrarily, divided into two sections: the *Monothalamia* and the *Polythalamia*. In the first of these sections (*fig.* 4), comprising the so-called 'simple' or 'unilocular' *Foraminifera*, the shell consists of a single chamber, and the animal is, in fact, nothing more than a little mass of sarcode enveloped in a calcareous covering. *Lagena*, with its beautiful flask-shaped shell, may be taken as the type of this division. In the *Polythalamia*, or 'multilocular' *Foraminifera*,

Fig. 4.—Monothalamous Foraminifera. *a. Lagena sulcata. b.* Adult form of the same. *c. Lagena malo.*

the shell is composed of many chambers separated from one another by divisional walls or 'septa' (*fig.* 5), each of which is perforated by one or more openings, 'septal apertures,' by means of which the sarcode occupying the different chambers is united into a continuous and organic whole, the connecting bands being called 'stolons.' Complex as their structure often is, the compound *Foraminifera* are, nevertheless, formed by a process of continuous gemmation or budding from a single 'primordial segment' in every respect identical with the permanent condition of a *simple* species. They commence their existence, therefore, as *Monothalamia*, and are converted into *Polythalamia* merely by a process of 'vegetative' or 'irrelative repetition.' As their development proceeds, the primitive

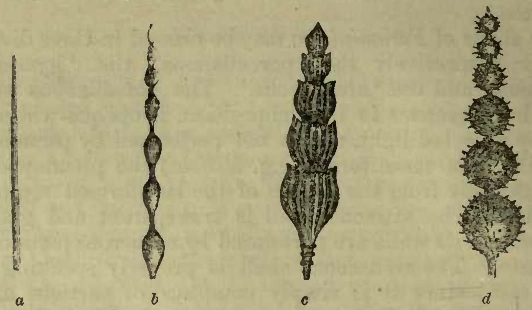


Fig. 5.—Polythalamous Foraminifera. *a. Nodosaria rugosa. b. N. longisulcata. c. N. spinicosta. d. N. hispida.*

mass of sarcode, or 'primordial segment,' throws out fresh segments in the form of buds according to a determinate law; and it is upon the direction in which these segments are evolved that the ultimate form of the shell depends. The more important variations in this respect are as follows:—If the additional segments are added to the primordial chamber in a linear series, so as to form a straight or slightly curved line, we obtain respectively a *Nodosaria* (*fig.* 5) or a *Dentalina.* When the new chambers are added in a spiral direction, each being a little larger than the one which preceded it, and the coils of the spiral lying in one plane, then we get the 'nautiloid' shell, so common amongst the *Foraminifera* (*fig.* 6 *a*).

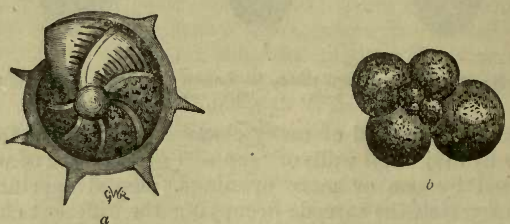


Fig. 6.—*a. Robulina echinata,* a 'nautiloid Foraminifer.' *b. Globigerina bulloides.*

This type of shell is so closely similar to the shape of the pearly nautilus, that the older naturalists were long in the habit of classing these forms along with the *Cephalopoda*, or Cuttle-fish order. In the true nautiloid shell the convolutions of the spiral lie in a single plane, as in *Rotalina*, and the shell is said to be 'equilateral.' In other cases, however, the spiral passes obliquely round a central axis, and the shell becomes conical or turreted, when it is said to be 'inequilateral' or 'trochoid.' In other forms, such as *Nummulites* and *Orbitolites*, the structure of the shell, though regular, is much more complicated. Besides these symmetrical forms, there exist others in which the arrangement of the segments is very irregular, as is seen in *Globigerina*, *Acervulina*, &c. (*fig.* 6 *b*).

Besides the true pseudopodial foramina with which the walls of the test in most of the *Foraminifera* are pierced, there exists in some forms an additional system of complicated branching and anastomosing tubes, which are distributed between the laminæ of the shell, and establish a communication between its external and internal surfaces.

Classification of Foraminifera.—The classification of the *Foraminifera* has hitherto proved a matter of extreme difficulty, and probably none of the arrangements as yet proposed can be considered as more than provisional. The following is the classification adopted by Dr. Carpenter, who is one of the greatest living authorities upon the group.

Order Reticulosa. (= Foraminifera.)—*Rhizopods showing no differentiation, or a very imperfect one, into ectosarc and endosarc; no nucleus or contractile vesicle; pseudopodia filamentous, minutely subdivided, and inosculating freely to form a net-work.*

Section 1. *Imperforata.*—Envelope membranous or calcareous, the walls not perforated by apertures for the pseudopodia, which are emitted solely from the single or multiple aperture of the shell.

Families. 1. *Gromida.* Test membranous.
2. *Miliolida.* Test porcellanous.
3. *Lituolida.* Test arenaceous.

Section 2. *Perforata.*—Envelope calcareous (hyaline or vitreous) or rarely arenaceous, its walls traversed by numerous foramina for the emission of pseudopodia.

The following classifications by D'Orbigny and Schultze are founded merely upon the form of the shell, and, as such, are purely arbitrary. Of the two Schultze's arrangement is probably the more satisfactory.

TABLE OF D'ORBIGNY'S ARRANGEMENT OF THE FORAMINIFERA.

Order 1. *Monostega.*—Body consisting of a single segment; the shell of a single chamber.

Order 2. *Stichostega.*—Segments arranged in a single row, in a straight or slightly curved line.

Order 3. *Helicostega.*—Segments arranged in a spiral, the shell forming a number of convolutions. (The 'nautiloid' *Foraminifera.*)

Order 4. *Entomostega.*—Segments arranged on two alternating axes forming a spiral.

Order 5. *Enallostega.*—Segments arranged on two or three alternating axes, not forming a spiral.

Order 6. *Agathistega.*—Chambers wound round an axis; each segment embracing half the entire circumference.

TABLE OF SCHULTZE'S ARRANGEMENT OF THE FORAMINIFERA.

Section 1. *Helicoidea.*—Segments arranged in a convolute series.

Section 2. *Rhabdoidea.*—Segments placed in a direct line.

Section 3. *Soroidea.*—Segments disposed in an irregular manner.

AFFINITIES OF FORAMINIFERA.—The *Foraminifera* are related on the one hand to the *Amœbea* and on the other to the *Spongida.* From the former the 'unilocular' *Foraminifera* differ both in the possession of an external envelope, and in the much less highly differentiated characters of their sarcode; but the points of resemblance are obvious, and in such forms as *Actinophrys* and *Lieberkühnia* we are presented with an apparent transition between the two orders. From the shelled *Amœbea*, such as *Arcella*, the *Foraminifera* are broadly separated by the absence in the former of pseudopodial pores, and are fundamentally distinguished by the different nature of the sarcode-body.

To the Sponges the *Foraminifera* are related in various ways, one of the most striking links being found in *Carpenteria*, a singular attached form of *Foraminifer.* The shell, namely, of *Carpenteria* is conical and calcareous, composed of an aggregation of chambers arranged in a spiral, and having its walls perforated by numerous foramina of a minute size. The interior of the chambers, however, is filled with 'a fleshy sponge-like body,' strengthened by numerous spicula.

BATHYBIUS, COCCOLITHS, AND COCCOSPHERES.—It may be as well to notice here a singular organism which is certainly referable to the *Rhizopoda*, though its exact affinities are doubtful. Certain minute oval or rounded bodies have long been known as occurring attached to the surface of the shells of *Foraminifera*, and they were originally described by Professor Huxley under the name of *coccoliths.* Subsequently it was discovered by Dr. Wallich that these singular bodies occur not only in the free condition, but also attached to the external surface of little spherical masses of sarcode to which he gave the name of *coccospheres*. The *coccospheres* are enclosed in a delicate envelope apparently of a calcareous nature, and are studded at nearly regular intervals by the *coccoliths*. More recently still, it has been discovered by Professor Huxley that both the *coccoliths* and the *coccospheres* are imbedded in masses of protoplasmic or sarcodic substance, covering wide areas of the sea-bottom, to which they bear the same relation that the spicules of sponges or of *Radiolaria* do to the soft parts of these animals. To this undefined and diffused protoplasm with its contained *coccoliths* and *coccospheres* the name *Bathybius* has been applied by Professor Huxley. Its exact position, as already said, is doubtful; but it is believed by Dr. Carpenter to be a rudimentary form of the *Foraminifera*, and to be somewhat allied to the ancient *Eozoön*.

Distribution of Foraminifera in Space.—The *Foraminifera* are mostly marine, and are found in almost all seas, though more abundantly in those of the warmer parts of the globe. It is concluded by Dr. Carpenter that 'the foraminiferous *fauna* of our own seas probably presents a greater range of variety than existed at any preceding period; but there is no indication of any tendency to elevation towards a higher type.' One of the most remarkable facts about their distribution at the present day, is the existence of a deposit at great depths in the Atlantic, formed almost entirely of the shells of *Foraminifera* and very closely resembling chalk. It has, further, been quite recently established that there co-exist with these *Foraminifera* various animals of a higher grade, some of which closely resemble, or are even specifically inseparable from, well-known cretaceous species. There is, therefore, some reason to conclude that the bottom of the sea at great depths is peopled at the present day by a fauna which is very closely allied to that of the Chalk.

Distribution of Foraminifera in Time.—Remains of *Foraminifera* have been found in Palæozoic, Mesozoic, and Kainozoic formations. In the oldest stratified rocks with which we are acquainted, viz. the Laurentian rocks of Canada, there occurs a singular body which has been described as the remains of a gigantic *Foraminifer*, under the name of *Eozoön Canadense*. If truly organic, as is doubted by some, it is the oldest fossil as yet discovered. It appears to have grown in reef-like masses resembling the sessile patches of *Polytrema* and *Carpenteria*, to both of which, as well as to the extinct *Nummulites*, it shows a decided affinity. In the Silurian rocks remains of *Foraminifera*, some of which are apparently identical with existing forms, have been detected in various places, and it is not improbable that the large Silurian fossils known as *Receptaculites* and *Stromatopora* should really be referred to this order. In the Carboniferous rocks of Russia whole beds are composed of a species of *Fusulina*. In the Secondary rocks *Foraminifera* occur in great abundance, the widely-spread formation known as the Chalk being crowded with these organisms. Chalk itself, in fact, is almost entirely composed of the cases of *Foraminifera*, some of which are identical with species now existing.

In the Tertiary rocks the *Foraminifera* attain their maximum of development, both as regards the size and the number of the forms which characterise them. The period of the Middle Eocene is especially distinguished by a very widely-spread and easily recognised rock known as the Nummulitic Limestone, so called from the abundance in it of a large coin-shaped *Foraminifer*, termed the *Nummulite*. The Nummulitic Limestone stretches from the West of Europe to the frontiers of China, but in some cases, in place of *Nummulites* proper, it contains the remains of a mimetic form termed *Orbitoides*. Upon the whole, Dr. Carpenter concludes that 'there is no evidence of any fundamental modification or advance of the foraminiferous type from the Palæozoic period to the present time.'

CHAPTER IV.

RADIOLARIA.

The order *Radiolaria* was founded by Müller to include the *Polycystina*, the *Acanthometrina*, and the *Thalassicollida*, to which Dr. Carpenter adds *Actinophrys* and its allies, chiefly on account of the form of the pseudopodia. Here, however, the term will be employed to designate the first three of these, and *Actinophrys* will be placed amongst the *Amœbea*, to which its alliance appears to be more decided.

The order *Radiolaria* may be defined as comprising those *Rhizopods which possess a siliceous test or siliceous spicules, and are provided with pseudopodia which stand out like radiating filaments, and occasionally run into one another.*

I. Family Acanthometrina.—The *Acanthometræ* are all marine, and consist of sarcode-bodies which are supported by a framework of radiating siliceous spines, the extremities of which usually project considerably beyond the body. The substance of the body admits of division into an outer membranous layer, or 'ectosarc,' and an internal granular layer, or 'endosarc.' The siliceous spines are hollow, being grooved at the base by a gutter which is continued further up the spine by a canal terminating at the apex of the spine by a distinct aperture. The spines in consequence of this structure are able to serve for the transmission of the pseudopodia, which gain the exterior by running through the canals and escaping at their apices. Many of the pseudopodia, however, do not occupy the canals of the spines.

II. FAM. POLYCYSTINA.—The members of this family are closely related to the *Foraminifera*, differing from them chiefly in the fact that their shells are composed of flint instead of carbonate of lime, as in most of the latter. They possess a body of sarcode, which is enclosed in a foraminated siliceous shell, which is often furnished with spine-like processes, and is usually of great beauty (*fig.* 7). The sarcodic substance of the body is olive-brown in colour with yellow globules, and often does not entirely fill the shell. The pseudopodia are emitted through the foramina in the test, and are long, ray-like filaments, which display a slow movement of granules along their borders.

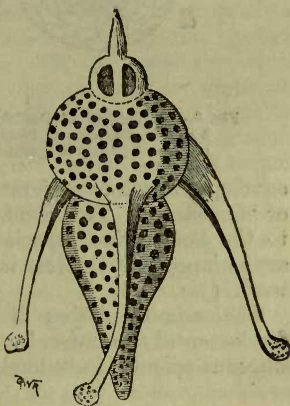


Fig. 7.—Polycystina. *Rhopalocanium ornatum*, showing the pseudopodial foramina.

The *Polycystina* are all microscopic, and are all inhabitants of the sea, having a very wide distribution. They are also found abundantly in certain Tertiary deposits, being often erroneously described as *Diatomaceæ*.

III. FAM. THALASSICOLLIDA.—The *Thalassicollida* have been defined as being *Rhizopoda which are 'provided with structureless cysts containing cellular elements and sarcode, and surrounded by a layer of sarcode, giving off pseudopodia, which commonly stand out like rays, but may and do run into one another, and so form net-works.'*—(Huxley.)

The three best known genera of the family are *Sphærozoüm*, *Collosphæra*, and *Thalassicolla*. They are all marine, and vary in size from an inch in diameter downwards. *Sphærozoüm* consists essentially of a number of spherical sarcode bodies (sometimes called 'cellæ-form bodies') with distinct nuclei, surrounded by a zone of siliceous spicules, the whole being imbedded in a common gelatinous matrix. The centre of the mass is vacuolated, sometimes to such an extent that it becomes a hollow sphere.

In *Collosphæra* the spherical body—which is very like that of the preceding form—is enclosed in a transparent siliceous

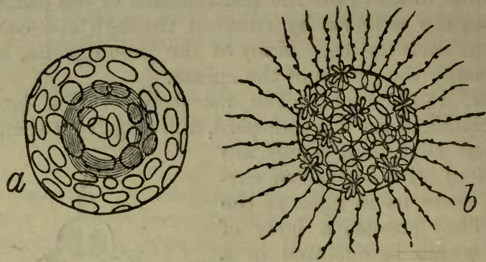


Fig. 8.—Morphology of Radiolaria. *a.* Siliceous fenestrated test of *Collosphæra Huxleyi.* *b. Thalassicolla morum*, showing cellæform bodies, compound groups of spicules, and radiating pseudopodia.

envelope, which is perforated by numerous rounded apertures or 'fenestræ.' This form, therefore, approaches very closely to the *Polycystina*, especially to those in which the foramina are so large that the test is reduced to a mere reticulate framework (*fig.* 8 *a*).

Thalassicolla differs little from either of the above in fundamental structure, but it contains a number of compound siliceous spicules imbedded in its ectosarc (*fig.* 8 *b*).

CHAPTER V.

SPONGIDA.

The true nature of sponges has long been a matter of dispute, but they are now almost universally referred to the animal kingdom, and placed either in or near the *Rhizopoda*. Some observers still maintain the vegetable nature of sponges, but this opinion has no real grounds for its support, and is chiefly founded upon loose analogies and upon a certain similarity in outward form.

The *Spongida* may be defined as '*sarcode-bodies, destitute of a mouth, and united into a composite mass, which is traversed by canals opening on the surface, and is almost always supported by a framework of horny fibres, or of siliceous or calcareous spicula.*'—(Allman.)

From the above definition it will be seen that a sponge is composed essentially of two elements, a soft gelatinous investing 'flesh,' and an internal supporting framework or 'skeleton.'

Taking an ordinary horny sponge as the type of the order, we find it to be composed of a skeleton of horny reticulated fibres which interlace in every direction, and are pierced by numerous apertures, the whole surrounded externally and internally by a gelatinous glairy substance, like white of egg, the so-called 'sponge-flesh.' The horny skeleton is composed of a substance called 'keratode,' and is usually strengthened by spicula of lime or flint, which also occur less abundantly in the sponge-flesh. These must not, however, be confounded with the skeleton of the true calcareous or siliceous sponges in which the keratode is wanting. Of the apertures which penetrate the substance of the sponge in every direction, some are large crateriform openings, and are termed 'oscules,' or 'exhalent apertures;' whilst others, which occur in much greater numbers, are greatly smaller in size and are termed 'pores' or 'inhalent apertures.' The 'sponge-flesh' which invests the entire skeleton is found upon a microsopical examination to be entirely composed of an aggregation of rounded amœbiform bodies—the so-called 'sponge-particles' or 'sarcoids' (*fig.* 2 *c*, *d*, *e*). Some of these are ciliated; whilst others are capable of emitting pseudopodia from all parts of their surface, and are provided with nuclei, thus coming closely to resemble so many *Amœbæ*. Regarding the skeleton as something superadded, we may, in fact, look upon a sponge as being essentially nothing more than an aggregation of *Amœbæ*, since each 'sarcoid' is capable of procuring and assimilating food for itself in a manner strictly analogous to what we have seen in the *Amœba*.

In a living sponge a constant circulation of water is maintained by means of an aquiferous system (*fig.* 9), which is constituted by the oscula and pores—already alluded to—and by a system of canals, excavated in the substance of the sponge, and uniting the two sets of apertures. The water passes in by the 'pores' or inhalent apertures, and is conveyed by a series of canals—the 'incurrent' or 'afferent' canals—to a second series of tubes—the 'excurrent' or 'efferent canals'—by which it reaches the 'oscula' and is finally expelled from the body. These processes are regularly performed, and their mechanism was long a subject of speculation. It is now known, however, that beneath the superficial layer or 'dermal membrane' of the sponge there exist chambers lined with sponge-particles which are provided with vibratile filaments or cilia (*fig.* 9 *c*, *c*). The pores open into these chambers, and from them proceed the incurrent canals, each being dilated at its commencement into a sac, which is also lined with ciliated sponge-particles. By the

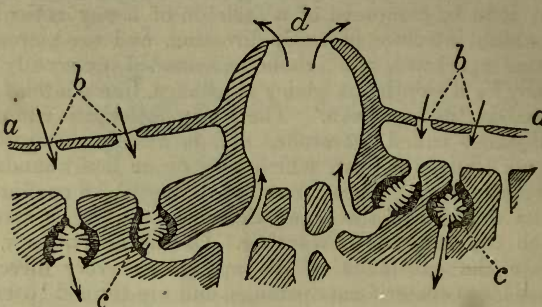


Fig. 9.—Diagrammatic section of *Spongilla* (after Huxley). *a a.* Superficial layer or 'dermal membrane.' *b b.* Inhalent apertures or 'pores.' *c c.* Ciliated chambers. *d.* An exhalent aperture or 'osculum.' The arrows indicate the direction of the currents.

vibratile action of these cilia currents of water are caused to set in by the pores, and as out-going currents proceed from the oscula a constant circulation of fresh water is maintained through the entire sponge. In this way each individual sponge-particle is enabled to obtain nutriment; the process being at the same time not improbably a rudimentary form of respiration.

The reproduction of sponges may be effected either asexually or sexually, the following being a brief outline of the phenomena which have been observed in the common fresh-water sponge (*Spongilla*), in which the process has been most accurately noticed.

In the first or asexual method of reproduction, which takes place in the winter, the deeper portions of the sponge are found to be filled with small seed-like rounded bodies, termed 'gemmules' or 'spores,' each of which possesses a small aperture or 'hilum' at one point. Each gemmule is composed of an outer coriaceous capsule surrounded by a layer of peculiar asteroid spicula, resembling two toothed wheels united by an axle, and termed 'amphidiscs.' These amphidiscs are imbedded in sarcode, whilst their inner surfaces rest upon the tesselated capsule already mentioned. The contents of the capsule are mostly sponge-particles which have developed ovules in their interior. When the spring comes, these 'ovi-bearing cells' are discharged through the 'hilum' of the gemmule into the water, and the liberated ovules are developed into new *Spongillæ*.

Spongilla also appears to reproduce itself in a somewhat analogous manner by means of what are termed 'swarm-spores.' These are small bodies, containing reproductive germs, and provided with numerous cilia by which they move about actively, becoming finally attached to some solid body, and developing themselves into the adult sponge.

In the second, or sexual, method of reproduction, certain of the sponge-particles or 'sarcoids' separate themselves and become nucleolo-nucleated, thus coming to resemble ova. At the same time other sarcoids become motionless, and their contents become molecular and are finally converted into spermatozoa. By the rupture of these and by the consequent contact of the different elements, embryos are produced, which are at first ciliated and move about freely, becoming eventually stationary and developing into new individuals.

Classification of the Sponges.—The *Spongida* have been variously classed, and a good natural arrangement is still a *desideratum*. By Dr. Bowerbank they are somewhat arbitrarily arranged in three orders, viz. the *Keratosa*, the *Silicea*, and the *Calcarea*, of which the first is believed to hold the lowest place. In the *Keratosa* the skeleton is composed of interlacing horny fibres, usually strengthened by spicula either of flint or lime. In the *Calcarea* the skeleton is composed of carbonate of lime; whilst in the *Siliceous* sponges it is composed either of spicules of silex, or 'of solid, laminated, and continuous siliceous fibre.' The nature of the skeleton thus varies considerably, whilst the spicules show almost indefinite modifications of shape, though they are constant for any given species, in any given part of its organisation. The sponge-flesh is much more uniform in its nature and composition. It may be noticed, however, that in *Spongilla* the sponge-particles are filled with green granules, which are apparently identical in chemical composition with the green colouring matter of plants (*chlorophyll*). In *Grantia*, too, the sarcoids are furnished with long filamentous appendages or cilia (*fig*. 2 *d*).

Distribution of Sponges in Space.—Sponges are almost exclusively marine, and are of almost universal occurrence. The sponges of commerce are mostly obtained from the Grecian Archipelago and the Bahama Islands. Recently the existence of numerous siliceous sponges at great depths in the ocean has been demonstrated by Drs. Carpenter and Wyville Thomson. They are associated with numerous *Foraminifera* and with *Crinoidea*, the whole assemblage bearing a singularly close resemblance to the fauna of the Cretaceous epoch.

Distribution of Sponges in Time.—Remains of sponges are known to occur in formations belonging to the Palæozoic, Mesozoic, and Kainozoic epochs. The keratose or horny sponges are obviously incapable of leaving any evidence of their existence, otherwise than by the preservation of the spicula with which the skeleton is furnished; and such are occasionally found, though they are of rare occurrence. The calcareous sponges are found from the Silurian rocks upwards, attaining their maximum in the seas of the Secondary epoch, the Chalk being especially characterised by their presence. The most important group of fossil sponges is that known as the *Petrospongiadæ*, characterised by the possession of a stony reticulate framework or skeleton, and by the absence of spicula. The most important genera of this group are *Sparsispongia* (Devonian) and *Ventriculites* (Chalk).

Of the Palæozoic sponges, *Archæocyathus* is found in the Potsdam sandstone of North America (Upper Cambrian ?); *Palæospongia* and *Acanthospongia* are familiar Lower Silurian forms; and *Amphispongia* and *Favospongia* occur along with other forms in the Ludlow rocks. In the Devonian rocks sponges occur pretty frequently, *Sparsispongia* being the commonest genus. (The Devonian *Steganodictyum* is really the cephalic buckler of a *pteraspidean* fish.) The most important Mesozoic genera of sponges are *Ventriculites* and *Siphonia*; and the order appears, upon the whole, to attain its maximum in the Cretaceous epoch. There seems no reason to doubt but that many of the chalk-flints owe their origin to sponges; and in some sections of flint are found 'minute spherical bodies covered with radiating and multicuspid spines,' which have been termed *Spiniferites* or *Xanthidia*, and are probably the 'gemmules' of sponges. (By some, however, these bodies are regarded as being the 'sporangia' of *Desmidiæ*, an order of the *Protophyta*.) Many Cretaceous and Tertiary shells are found to be mined by a species of boring sponge, which is nearly allied to the recent *Cliona*.

Affinities of Sponges.—As already pointed out, the sponges are allied both to the *Amœbæ* and to the *Foraminifera*. Indeed the individual 'sarcoids' or sponge-particles can scarcely be distinguished, when detached, from *Amœbæ*. The sponges show likewise a decided relationship to the *Radiolaria*; and by Professor James Clark, they are believed to be nearly allied to the 'flagellate' *Infusoria*.

CHAPTER VI.

INFUSORIA.

THE *Infusoria* of many writers comprise many of the lowest forms of plants—such as the *Diatoms*—together with the *Rotifera*, a class of minute animals now known to belong to the *Annuloida.* By modern writers, however, the term *Infusoria* is used strictly to designate those *Protozoa* which possess a mouth and rudimentary digestive cavity. They are, for this reason, often called collectively the 'stomatode' *Protozoa* in contradistinction to the remaining members of the sub-kingdom, which are all 'astomatous.' The name *Infusoria* itself is derived from the fact that the members of the class are often developed in organic infusions.

The *Infusoria*, or *Stomatode Protozoa*, may be defined as *Protozoa which are provided with a mouth and rudimentary digestive cavity, which do not possess the power of emitting pseudopodia, but which are furnished with vibratile cilia, or with contractile filaments. They are mostly microscopic in size, and their bodies usually consist of three distinct layers.*

The *Infusoria* may be divided into three orders, viz.:—*Suctoria*, *Ciliata*, and *Flagellata*, of which the second comprises the majority of the members of the class, and alone requires much consideration.

I. ORDER CILIATA. — This order comprises those *Infusoria in which the outer layer of the body is more or less abundantly furnished with vibratile cilia, which serve either for locomotion or for the procuring of food.* As types of the order *Paramœcium* and *Vorticella* may be selected, the former being free, whilst the latter is permanently fixed in its adult condition.

Paramœcium (*fig.* 10 *c*) is a slipper-shaped animalcule, composed externally of a structureless transparent pellicle— the 'cuticle,' which is lined by a layer of firm and consistent sarcode, which is termed the 'cortical layer,' or the 'parenchyma of the body,' this in turn passing into a central mass of softer and more diffluent sarcode, known as the 'chyme-mass,' or 'abdominal cavity.' The 'cuticle' is covered with vibratile cilia, and is perforated by the aperture of the mouth. The mouth leads into a funnel-shaped gullet, which is not continued into any distinct digestive sac, but is lost in the central 'chyme-mass.' Within the 'cortical layer' are the 'nucleus' and 'nucleolus,' and the 'contractile vesicle' (or vesicles). The nucleus is a solid band or rod-shaped body, having a small spherical particle applied to its exterior. This latter is the so-called 'nucleolus,' which must be carefully distinguished from the nucleolus of a cell, which occurs in the *interior* of the nucleus. The contractile vesicles are clear spaces, which contract and dilate at intervals, and occasionally exhibit radiating canals passing into the surrounding sarcode. It has also been maintained that the contractile vesicles communicate with the exterior of the body, but proofs are wanting on this point. Whether this should ultimately be established or not, there can be little doubt but that the vesicles are a rudimentary form of vascular apparatus. Certain other spaces termed 'vacuoles' are generally visible in addition to the contractile vesicles. These, however, are probably merely collections of water surrounding the particles of ingested food, and performing with them a circulation in the abdominal cavity, something like the circulation of granules which is seen in certain vegetable cells. It was the appearance of these 'vacuoles'—which are certainly not permanent organs of any kind—which induced Ehrenberg to term the *Infusoria* the 'Polygastrica,' upon the belief that they were so many stomachs.

Paramœcium obtains its food by means of the currents of water which are set up by the constantly vibrating cilia. The nutritive particles thus brought to the mouth pass into the central abdominal cavity, along with the contents of which they undergo the circulation above spoken of. Indigestible and fæcal particles appear to be expelled by a distinct anal aperture, which is situated near the mouth.

Reproduction in *Paramœcium* is effected either non-sexually by fission (*i.e.* by a simple division of its substance) or by a true sexual process. In this latter method two *Paramœcia* come together, and adhere closely to one another by their ventral surfaces. The 'nucleus,' which is truly an *ovary*, enlarges, and a number of ovules are formed in its interior. In like manner, the 'nucleolus' of each, which is really a *testis* or *spermarium*, also enlarges, and develops in its interior a number of fusiform or rod-like bodies, which are believed to be spermatozoa. The nucleolus of each then passes into the body of the other, the act of transference being effected through the mouth. Contact of the two reproductive elements then takes place, and a number of germs are produced, which, after their liberation from the body of the parent, are developed into adult *Paramœcia*.

Vorticella is a beautiful flower-like Infusorian which is commonly found in fresh water, adhering to the stems of aquatic plants. It consists of a bell-shaped body, or 'calyx,' supported upon the extremity of a slender contractile stem or 'pedicle.' The other extremity of the pedicle is fixed to some foreign body, and its power of contraction is due to the presence in its interior of a spiral contractile fibre, which is

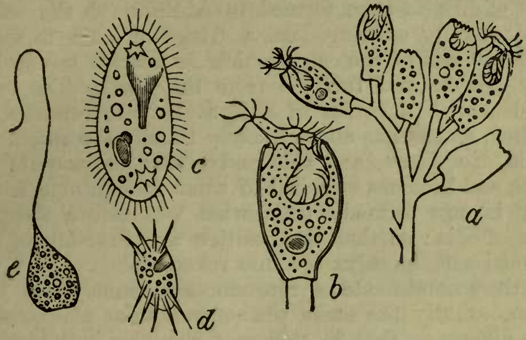


Fig. 10.—Morphology of Infusoria. *a. Epistylis*, a stalked Infusorian. *b.* A single calyx of the same greatly magnified, showing the ciliated disc which protrudes at will, and the ciliated internal cavity into which the particles of food are received. In the substance of the body are the contractile vesicle and smaller food-vacuoles. *c.* Diagrammatic representation of Paramœcium, showing the funnel-shaped gullet, the nucleus and nucleolus, food-vacuoles, and two contractile vesicles. *d. Aspidisca lynceus. e. Peranema globulosa*, a flagellate Infusorian.

sometimes called the 'stem-muscle.' The edge of the bell, or calyx, is surrounded by a projecting rim or border, called the 'peristome,' within which is a circular surface, the 'disc,' forming the upper extremity of the so-called 'rotatory organ.' The disc is surrounded by a fringe of vibratile cilia, forming a spiral line which is prolonged into the commencement of the digestive canal. Near the edge of the disc is situated the mouth, which conducts by its entrance or 'vestibulum' into a fusiform canal or 'pharynx,' which terminates abruptly in the abdominal cavity. The particles of food are taken in at the mouth, descend through the short alimentary canal, and enter the abdominal cavity, where they are subjected to the general rotation of the 'chyme-mass,' being finally excreted by an anal aperture which is situated near the mouth. As in *Paramœcium*, the body in *Vorticella* is composed of an outer 'cuticle,' a central 'chyme-mass,' and an intermediate 'cortical layer,' which contains a contractile vesicle and a band-like nucleus.

Reproduction in *Vorticella* may take place by fission, or by gemmation, or by a process of encystation and endogenous division. In the first of these modes the calyx becomes indented in a longitudinal direction, viz. from the pedicle to the disc, and the groove thus formed becomes gradually deeper until the calyx is finally divided into two halves supported upon the same pedicle. On one of these cups a 'posterior' circlet of cilia is then formed in addition to the 'anterior' circlet already existing (i.e. a fringe of cilia is developed round that end of the calyx which is nearest the attachment of the pedicle and furthest from the disc). The cup, thus furnished with a circlet of cilia at both extremities, is then detached, and swims about freely. Finally the *anterior* circlet of cilia disappears, and this end of the calyx puts forth a pedicle and becomes attached to some foreign object. A new mouth is now formed within what was before the *posterior* circlet of cilia; so that the position and function of the two extremities of the calyx are thus reversed.

In the second mode of reproduction, namely that by gemmation, exactly the same phenomena take place, with this single difference, that in this case the new individual is not produced by a splitting into two of the adult calyx but by means of a bud thrown out from near its proximal extremity. This bud is composed of a prolongation of the cuticular and cortical layers of the adult with a cæcal diverticulum of the abdominal cavity or chyme-mass. It soon develops a posterior circlet of cilia, the connection with the parent is rapidly constricted until complete separation is effected, and then the process differs in no respect from that described as occurring in the fissiparous method of reproduction.

In the third mode of reproduction the *Vorticella* encysts itself in a capsule, the cilia and pedicle disappear, and the nucleus breaks up into a number of rounded germs which are ultimately liberated by the rupture of the cyst, and, after a short locomotive stage, develop themselves into fresh *Vorticellæ*. How far this process may be truly sexual is not known, and no form of unequivocal sexual reproduction has hitherto been shown to occur in the case of *Vorticella*.

Epistylis is a not uncommon form of fixed Infusorian which is nearly allied to *Vorticella*, and differs chiefly in the fact that the pedicle is much branched and is rigid and not contractile. *Epistylis* (*fig.* 10 *a*) usually occurs in the form of a greyish-white nap on the stems of water-plants, or on the head of the common water-beetle, the *Dytiscus marginalis*. It consists of a plant-like branching and re-branching frond, the stems of which are quite transparent and faintly striated, but are not contractile, though capable of movement from side to side. Each branch of the entire colony terminates in an oval calyx, articulated to the stem by a distinct joint, upon which it can move from side to side. The calyces are oval or somewhat campanulate, but have the power of altering their dimensions, and especially of contracting so as to shorten their antero-posterior diameter. Each calyx terminates distally in a slightly elevated annular aperture, the margins of which are regularly toothed. The calyx appears to be formed by a hardening of the cuticle, and to form a distinct case, with a double margin, inclosing the animal. The sarcode body enclosed within this outer envelope is of a light brown colour and full of minute granules, with larger food-vacuoles and a well-marked contractile vesicle, which contracts and dilates two or three times a minute. The animal can retract itself entirely within its cup, and can at will exsert a ciliated disc. This disc (*fig.* 10 *b*) is inversely conical and acts as a kind of plug, and it is provided with two tufts of long cilia, one on each side. On one side of the protrusible disc is the oral aperture, which is continued by a distinct and well marked gullet into a central ill-defined cavity. Both the entrance of the gullet and the bottom of the central cavity are provided with very long, actively vibrating cilia, some of which are almost setiform. The entire granular contents of the abdominal cavity undergoes a constant though slow rotation.

Carchesium is another form which is like *Epistylis* in consisting of a number of calyces supported upon a branched pedicle, but differs from *Epistylis* and agrees with *Vorticella* in the fact that the pedicle is contractile.

Stentor, or the trumpet-animalcule, is another common Infusorian which is closely related to *Vorticella*. It consists of a trumpet-shaped calyx, devoid of a pedicle, but possessing the power of attaching and detaching itself at will. When detached it swims by means of the anterior circlet of cilia, just as the calyx of *Vorticella* will, if broken from its stalk. In *Vaginicola* the essential structure is much the same as in *Vorticella*, but the body is protected by a membranous or horny case ('carapace' or 'lorica') within which the animal can retire.

Amongst the structures of the *Infusoria* which require some notice, are the 'pigment spot' and the 'tricho-cysts.' The pigment spot is a brightly coloured solid particle, generally red, of very common occurrence in many *Infusoria*, but of quite unknown function. The 'tricho-cysts' are vesicular bodies, capable of emitting thread-like filaments, and greatly resembling the urticating cells of many of the *Cœlenterata*. They have been detected in *Bursaria*, as well as in other members of this order.

II. Order Suctoria.—This order includes a series of *Infusoria* of a very anomalous nature. In *Acineta*, which may be taken as the type, the body is covered with a number of radiating filamentous tubes, which are furnished at their extremities with suctorial discs, and are capable both of exsertion and retraction. These retractile tubes both seize the prey, and serve as vehicles for the ingestion of food ; hence the term 'polystome,' or many-mouthed, has been proposed for the order by Professor Greene.

III. Order Flagellata.—This order comprises those *Infusoria* which, like *Peridinium*, find their means of locomotion in long, flexible, lash-like filaments, termed 'flagella;' cilia occasionally being present as well. In some, as in *Peranema* (*fig.* 10 *e*), there is only a single one of these appendages; in others, as in *Anisonema*, there are two flagella; whilst in *Heteromastix* and *Pleuronema* we have forms apparently transitional between the *Ciliata* and the *Flagellata*, since both cilia and flagella are present in these genera. In all their other essential characters, the flagellate *Infusoria* do not differ from the more typical members of the class.

Noctiluca.—Amongst the numerous organisms which contribute to the phosphorescence of the sea,* one of the commonest is the animalcule known as *Noctiluca* (*fig.* 11), the true position of which has not yet been determined. It is nearly spherical in shape, having an indention, or 'hilum,' at one side, close to which is fixed a long filament, probably used in locomotion. The body consists of a 'cuticle' and 'cortical layer,' enclosing a central mass of sarcode. Near the filament there is a minute oral aperture leading into a short digestive cavity. A nucleus and vacuoles are also present. From the presence of a mouth and from its general structure, *Noctiluca* should be probably be looked upon as a flagellate *Infusorian*, but it is placed by M. de Quatrefages amongst the *Rhizopoda*.

Affinities of the Infusoria.—Though generally placed amongst the *Protozoa*, of which they form the highest division,

* The *diffused* luminosity of the sea is mainly due to the *Noctiluca miliaris*; but its partial luminosity is due to various phosphorescent animals, amongst which are the *Physalia utriculus* (the Portuguese-man-of-war), *Medusæ*, *Tunicata*, *Annelides*, &c. The cause of phosphorescence is variously stated, being supposed very generally to be caused by a process of slow combustion analogous to that which takes place in phosphorus when exposed to the atmosphere. Upon the whole, however, it appears that the phenomenon is a vital process, consisting essentially in the conversion of nervous force (or vital energy) into light; just as the same force can be converted by certain fishes into electricity. This transformation often requires a special apparatus for its production, but it appears to be sometimes effected by the entire organism.

the position of the *Infusoria* cannot be looked upon as definitely settled. There is a growing opinion amongst competent authorities that the *Infusoria* should be entirely removed from

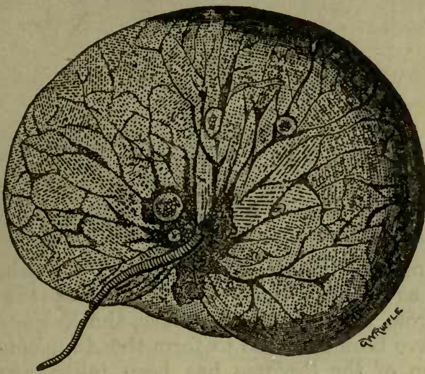


Fig. 11.—*Noctiluca miliaris*, greatly enlarged.

the *Protozoa*, and that they should be placed amongst the *Annuloida*, having their nearest allies in the *Turbellarian* Worms. If this change be carried out, the *Infusoria* and *Rotifera*, which older naturalists grouped together, and which modern observers have placed widely apart, will be again brought nearly together.

CŒLENTERATA.

CHAPTER VII.

THE SUB-KINGDOM CŒLENTERATA.

1. Characters of the Sub-Kingdom. 2. Divisions. 3. General Characters of the Hydrozoa. 4. Explanation of Technical Terms.

The sub-kingdom *Cœlenterata* (Frey and Leuckhart) may be considered as the modern representative of the *Radiata* of Cuvier. From the *Radiata*, however, the *Echinodermata* and *Scolecida* have been removed to form the *Annuloida*, the entire sub-kingdom of the *Protozoa* has been taken away, and the *Polyzoa* have been relegated to their proper place amongst the *Mollusca*. Deducting these groups from the old *Radiata*, the residue, comprising most of the animals commonly known as Polypes or Zoophytes, remains to constitute the modern *Cœlenterata*.

The *Cœlenterata* may be defined as *animals whose alimentary canal communicates freely with the general cavity of the body* ('*somatic cavity*'). *The substance of the body is made up of two fundamental membranes, an outer layer, called the* '*ectoderm,*' *and an inner layer, or* '*endoderm.*' *There are no distinct neural and hæmal regions, and in the great majority of the members of the sub-kingdom there are no traces of a nervous system. Peculiar urticating organs, or* '*thread-cells,*' *are usually present, and generally speaking a radiate condition of the organs is perceptible, especially in the tentacles with which most are provided. In all the Cœlenterata distinct reproductive organs have been shown to exist.* By Professor Allman the *Cœlenterata* have been defined as follows:—'Animals composed of numerous merosomes (body-segments), which are disposed radially round a longitudinal (antero-posterior) axis; frequently with a determinable antero-posterior and dorso-ventral plane (bilateral); a distinct body-cavity, which always communicates with the outer world through the mouth.'

With regard to the fundamental tissues of the *Cœlenterata*, there exist two primary membranes, of which one forms the outer surface of the body, and is called the 'ectoderm;' whilst the other lines the alimentary canal, the general cavity of the body, and the tubular tentacles, and is termed the 'endoderm.' These membranes correspond with the primitive serous and mucous layers of the germinal area, and become differentiated in opposite directions, the ectoderm growing from within outwards, the endoderm from without inwards. Each consists of numerous nuclear bodies, or 'endoplasts,' imbedded in a granular 'intercellular substance' or 'periplast;' and each may be rendered more or less complex by vacuolation or fibrillation.

In connection with the integument of the *Cœlenterata*, the organs termed 'thread-cells' ('cnidæ,' or 'nematocysts') must be noticed. These are peculiar cellular bodies, of various shapes, which probably serve as weapons of offence and defence, and which communicate to many members of the sub-kingdom (*e.g.* the Jelly-fishes) their well-known power of stinging. In the common *Hydra* the thread-cells consist of 'oval elastic sacs, containing a long coiled filament, barbed at its base, and serrated along its edges. When fully developed the sacs are tensely filled with fluid, and the slightest touch is sufficient to cause the retroversion of the filament, which then projects beyond the sac for a distance, which is not uncommonly equal to many times the length of the latter.'*—(Huxley.) (*Fig.* 12 *d.*) The *Cœlenterata* are divided into two classes, termed respectively the *Hydrozoa* and the *Actinozoa*.

Class I. Hydrozoa.

The *Hydrozoa* are defined as *Cœlenterata in which the walls of the digestive sac are not separated from that of the general body-cavity, the two coinciding with one another; the reproductive organs are in the form of external processes of the body-wall.* (*Fig.* 12 *a*, *b.*)

It follows from the above, that, since there is but a single internal cavity, the body of a *Hydrozoön* on transverse section appears as a single tube, the walls of which are formed by the combined digestive and somatic cavity.

The *Hydrozoa* are all aquatic, and the great majority are marine. The class includes both simple and composite organisms, the most familiar examples being the common Fresh-water Polype (*Hydra*), the Jelly-fishes (*Medusæ*), and the Portuguese man-of-war (*Physalia*). Owing to the great

* Thread-cells, though very commonly, if not universally, present in the *Cœlenterata*, are nevertheless not peculiar to them. Similar organs have been shown to exist in several of the *Nudibranchiate Mollusca*, as well as in some Annelides (*Spio seticornis*). There likewise exist analogous organs (*trichocysts*) in several of the *Infusoria*, and in the *Planarida*.

difficulty which is ordinarily experienced by the student in mastering the details of this class of animals, it has been thought advisable to introduce here a short explanation of some of the technical terms which are in more general use in describing these organisms.

General Terminology of the Hydrozoa.

Individual.—We have already seen (*see* Introduction) that the term 'individual,' in its zoological sense, must be restricted to 'the entire result of the development of a single fertilised ovum,' and that in this sense an individual may either be simple, like an *Amœba*, or may be composite, like a Sponge, which is produced by an aggregation of amœbiform particles. If all the parts composing an individual remain mutually connected, its development is said to be 'continuous;' but if any of these parts become separated as independent beings, the case becomes one of 'discontinuous' development.

Amongst the *Hydrozoa*, the individual may be either simple or compound, and the development may be either continuous or discontinuous, the following terms being employed to denote the phenomena which occur.

Hydrosoma.—This is the term which is employed to designate the entire body of a *Hydrozoön*, whether it be simple, as in the *Hydra*, or composite, as in a *Sertularian.*

Polypite.—The alimentary region of a *Hydrozoön* is called a 'polypite;' the term 'polype' being now restricted to the same region in the *Actinozoa.* In the simple *Hydrozoa* the entire organism may be called a 'polypite;' but the term is more appropriately applied to the separate nutritive factors which together make up a compound *Hydrozoön.*

Distal and Proximal.—These are terms applied to different extremities of the hydrosoma. It is found that one extremity grows more quickly than the other, and to this free growing end—at which the mouth is usually situated—the term 'distal' is applied. To the more slowly growing end of the hydrosoma —which is at the same time usually the fixed end—the term 'proximal' is applied. These terms may be used either in relation to a single polypite in the compound *Hydrozoa*, or to the entire hydrosoma, whether simple or compound.

Cœnosarc.—This is the term which is employed to designate the common trunk, which unites the separate polypites of any compound *Hydrozoön* into a single organic whole.

Zoöids.—In continuous development the partially independent beings which are produced by gemmation or fission by the primitive organism, to which they remain permanently attached, are termed 'zoöids.'

In discontinuous development, where certain portions of the 'individual' are separated as completely independent beings, these detached portions are likewise termed 'zoöids;' that which is first formed being distinguished as the 'producing zoöid,' whilst that which separates from it is known as the 'produced zoöid.' In a great number of Hydrozoa there exist two distinct sets of zoöids, one of which is destined for the nutrition of the colony, and has nothing to do with generation, whilst the functions of the other, as far as the colony is concerned, are wholly reproductive. For *the whole assemblage of the nutritive zoöids of a Hydrozoön* Professor Allman has proposed the term 'trophosome,' applying the term 'gonosome' to *the entire assemblage of the reproductive zoöids.* In such *Hydrozoa*, therefore, as possess these two distinct sets of zoöids, the 'individual,' zoologically speaking, is composed of a trophosome and a gonosome. It follows from this that neither the trophosome nor the gonosome, however apparently independent, and though endowed with intrinsic powers of nutrition and locomotion, can be looked upon as an 'individual,' in the scientific sense of this term.

CHAPTER VIII.

DIVISIONS OF THE HYDROZOA.

SUB-CLASS HYDROIDA.

THE *Hydrozoa* are divided into four sub-classes, viz. the *Hydroida*, the *Siphonophora*, the *Lucernarida*, and the *Discophora*.

SUB-CLASS I. HYDROIDA.—This sub-class comprises those *Hydrozoa which consist of an alimentary region or 'polypite,' which is provided with an adherent disc, or 'hydrorhiza,' and prehensile tentacles.*

In some few cases the hydrosoma is composed of a single polypite only, as in the *Hydrida* and in some of the *Corynida*; but usually there are several polypites united together by means of a common trunk or 'cœnosarc,' as in most of the *Corynida* and in the orders *Sertularida* and *Campanularida*. Further, in the great majority of cases the 'hydrorhiza' is permanently attached to some foreign object.

The *Hydroida* comprises four orders, viz. the *Hydrida*, the *Corynida*, the *Sertularida*, and the *Campanularida*.

ORDER I. HYDRIDA (*Gymnochroa*, Hincks). — This order comprises those *Hydrozoa whose 'hydrosoma' consists of a single locomotive polypite, with tentacles and 'hydrorhiza' and with reproductive organs which appear as simple external processes of the body-wall. The hydrorhiza is discoid, and no hard cuticular layer is at any time developed.*

The order *Hydrida* comprises a single genus only (*Hydra*), including the various species of 'Fresh-water Polypes,' as

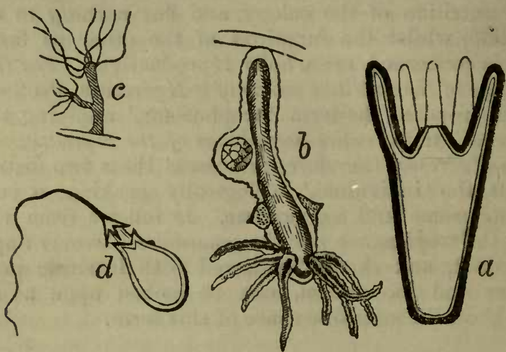


Fig. 12.—Morphology of Hydrozoa. *a.* Diagrammatic section of *Hydra.* The dark line is the ectoderm, the fine line and clear space adjacent are the endoderm. *b. Hydra viridis*, showing a single ovum contained in the body wall near the proximal extremity, and two elevations containing spermatozoa near the bases of the tentacles. *c. Hydra vulgaris* with an undetached bud. *d.* Thread-cell of the *Hydra*, greatly magnified.

they are often called. The common *Hydra* (*fig.* 12 *c*) is found abundantly in this country, and consists of a tubular cylindrical body, the 'proximal' extremity of which is expanded into an adherent disc, or foot—the 'hydrorhiza'—by means of which the animal can attach itself to some foreign body. It possesses, however, the power of detaching the hydrorhiza at will and thus of changing its place. At the opposite, or 'distal,' extremity of the body is placed the mouth, surrounded by a circlet of tentacles, which arise a little distance below the margin of the oral aperture. The tentacles vary in number from five to twelve or more, and they vary considerably in length in different species, being much shorter than the body in the *Hydra viridis*, but being extremely long and filamentous in *Hydra fusca*. They are highly extensile and contractile, and serve as organs of prehension. Each consists of a prolongation of both ectoderm and endoderm, enclosing a diverticulum of the somatic cavity, and they are abundantly furnished with thread-cells. The cylindrical hydrosoma is excavated into a single large cavity, lined by the endoderm, and communicating with the exterior by the mouth. This—the 'somatic cavity'—is the sole digestive cavity with which the *Hydra* is provided, the indigestible portions of the food being rejected by the mouth.

The *Hydra* possesses a most extraordinary power of resisting mutilation and of multiplying artificially, when mechanically divided. Into however many pieces a *Hydra* may be divided, each and all of these will be developed gradually into a new and perfect polypite. The remarkable experiments of Trembley upon this subject are well known, and have been often repeated, but space will not permit further notice of them here. Reproduction is effected in the *Hydra* both asexually by gemmation and sexually, the former process being followed in summer, and the latter towards the commencement of winter, few individuals surviving this season. In the first method the *Hydra* throws out one or more buds, generally from near its proximal extremity. These buds at first consist simply of a tubular prolongation of the ectoderm and endoderm, enclosing a cæcal diverticulum of the body-cavity; but a mouth and tentacles are soon developed, when the new being is usually detached as a perfect independent *Hydra*. The *Hydræ* thus produced throw out fresh buds, often before they are detached from the parent organism, and in this way reproduction is rapidly carried on.

In the second or sexual mode of reproduction, ova and spermatozoa are produced in outward processes of the body-wall (*fig.* 12 *b*). The spermatozoa are developed in little conical elevations, which are produced near the bases of the tentacles, and the ova are enclosed in sacs of much greater size, situated nearer the fixed or proximal extremity of the animal. Ordinarily there is but one of these sacs containing a single ovum, but sometimes there are two. When mature, the ovum is expelled through the body-wall, and is fecundated by the spermatozoa, which are simultaneously liberated. The embryo appears as a minute free-swimming ciliated body. The serous and mucous layers of the blastoderm (germinal area) correspond to the ectoderm and endoderm, and for the formation of the perfect *Hydra* nothing further seems wanting than the modification of one end of the body into a hydrorhiza, and the formation of a mouth and tentacles at the other.

ORDER II. CORYNIDA (= TUBULARIDA, the *Athecata* of Hincks).—The order *Corynida* comprises those *Hydrozoa*, *whose hydrosoma is fixed by a hydrorhiza, and consists either of a single polypite, or of several united by a cœnosarc, which usually develops a firm outer layer or 'polypary.' No 'hydrothecæ' are* present. '*The reproductive organs are in the form of gonophores, which vary much in structure, and arise from the sides of the polypites, from the cœnosarc, or from gonoblastidia.*'—(Greene.)

The hydrosoma of the *Corynida* may consist of a single polypite, as in *Coryomorpha* and *Vorticlava*, or it may be composed of several united by a cœnosarc, as in *Cordylophora* (*fig.* 13 *a*). The order is entirely confined to the sea, with

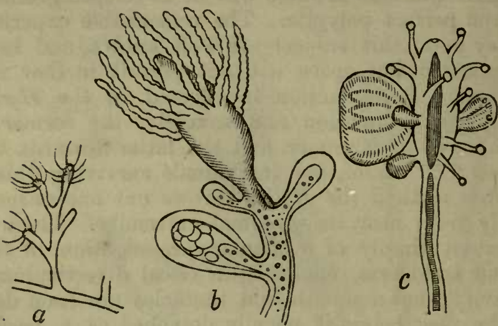


Fig. 13.—Morphology of Corynida. *a.* Fragment of *Cordylophora lacustris*, slightly enlarged. *b.* Fragment of the same considerably enlarged, showing a polypite and three gonophores in different stages of growth, the largest containing ova. *c.* Portion of *Syncoryne Sarsii* with medusiform zoöids budding from between the tentacles.

the single exception of *Cordylophora*, which inhabits fresh water. In *Tubularia* and its allies the organism is protected by a well-developed external chitinous envelope, or 'polypary;' but in the other genera belonging to the order the polypary is either rudimentary, or is entirely absent. The polypary of the *Corynida*, when present, is readily distinguished from that of the *Sertularida*, by the fact that in the former it extends only to the base of the polypites; whereas in the latter it expands to form little cups for the reception of the polypites, these cups being called 'hydrothecæ.'

As regards the reproductive process in the *Corynida*, the reproductive elements are developed in distinct buds or sacs, which are external processes of the body-wall, and have been aptly termed 'gonophores' by Professor Allman. Great variations exist in the form and development of these generative buds, and an examination of these leads us to some of the most singular phenomena in the entire animal kingdom. In some species of *Hydractinia* and *Coryne*, the generative buds or 'gonophores' exist in their simplest form, namely as protuberances of the endoderm and ectoderm, enclosing a diverticulum of the somatic cavity. In this form they are attached to the 'trophosome' by a short stalk, and they are termed 'sporosacs' (*fig.* 14 *a*). They are exactly like the buds which we have already seen to exist in the *Hydra*, with this difference, that they are not themselves developed into fresh polypites, but are simply receptacles in which the essential elements of generation—the ova and spermatozoa—are prepared, by the union of which the young *Corynid* is produced.

In *Cordylophora* (*fig.* 13 *b*) a further advance in structure is perceptible. The gonophore now consists of a closed sac, from the roof of which depends a hollow process or peduncle —the 'manubrium'—which gives off a system of tubes which run in the walls of the sac. For reasons which will be immediately evident, the gonophore in this case is said to have a 'disguised' medusoid structure (*fig.* 14 *b*).

In certain *Corynida*, however, we meet with a still higher form of structure, the gonophores being now said to be 'medusoid.' In these cases the generative bud is primitively a simple sac—such as the 'sporosac'—but ultimately develops itself into a much more complicated structure. The

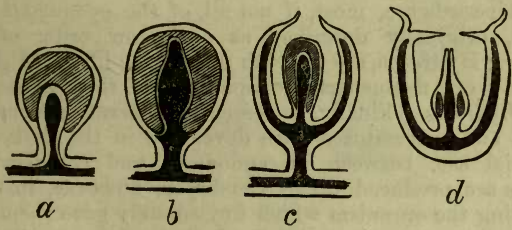


Fig. 14.—Reproductive processes of Hydrozoa. *a*. Sporosac. *b*. Disguised medusoid. *c*. Attached medusiform gonophore. *d*. Free medusiform gonophore. The cross shading indicates the reproductive organs, ovaria or spermaria. The part completely black indicates the cavity of the manubrium and the gonocalycine canals.

gonophore (*fig.* 13 *c*) is now found to be composed of a bell-shaped disc, termed the 'gonocalyx,' which is attached by its base to the parent organism (the trophosome), and has its cavity turned outwards. From the roof of the gonocalyx, like the clapper of a bell, there depends a peduncle or 'manubrium,' which contains a process of the somatic cavity. The manubrium gives out at its fixed or proximal end four prolongations of its cavity, in the form of radiating lateral tubes, which run to the margin of the bell, where they communicate with one another by means of a single circular canal which surrounds the mouth of the bell. This system of tubes constitutes what is known as the system of the 'gonocalycine canals.' The gonophore, thus constituted, may remain permanently attached to the parent organism, as in *Tubularia indivisa* (*fig.* 14 *c*); but in other cases still further changes ensue. In the higher forms of development (*fig.* 14 *d*) the manubrium acquires a mouth at its free, or distal, extremity, and the gonocalyx becomes detached from the parent. The gonophore is now free, and behaves in every respect as an independent being. The gonocalyx is provided with marginal tentacles and with an inward prolongation from its margin, which partially closes the mouth of the bell, and is termed the 'veil' or 'velum.' By the contractions of the gonocalyx, which now serves as a natatorial organ, the gonophore is propelled through the water. The manubrium, with the shape, assumes the functions of a polypite, and its cavity takes upon itself the office of a digestive sac. Growth is rapid, and the gonophore may attain a comparatively gigantic size, being now absolutely identical with one of those organisms which are commonly called 'jelly-fishes,' and are technically known as *Medusæ* (*fig.* 20 *a*). In fact, as we shall afterwards see, most, if not all, of the *gymnophthalmate Medusæ*, originally described as a distinct order of free-swimming Hydrozoa, are in truth merely the liberated generative buds, or 'medusiform gonophores,' of the permanently-rooted *Hydroids*. Finally, the essential generative elements—the ova and spermatozoa—are developed in the walls of the manubrial sac, between its endoderm and ectoderm, and embryos are produced. These embryos, however, instead of resembling the organism which immediately gave them birth, develop themselves into the fixed *Corynid* from which the gonophore was produced, thus completing the cycle.

As we have seen, the generative buds of the Corynida may exist in the following forms:—1. As 'sporosacs,' or simple closed sacs, consisting of ectoderm and endoderm, with a central cavity in which ova and spermatozoa are produced. 2. As 'disguised medusoids,' in which there is a central manubrial process and a rudimentary system of gonocalycine canals; but the gonocalyx remains closed. 3. As complete medusoids, which have a central manubrium, a complete system of gonocalycine canals, and an open gonocalyx; but which never become detached. 4. As perfect medusiform gonophores, which are detached, and lead an independent existence for a time, until the generative elements are matured.

In whichever of these forms the gonophore may be present, the place of its origin from the trophosome may vary in different species of the order. 1. They may arise from the sides of the polypites, as in *Coryne* and *Stauridia*. 2. They may be produced from the cœnosarc, as in *Cordylophora*. 3. They may be produced upon certain special processes, which are termed 'gonoblastidia,' as in *Hydractinia* and *Dicoryne*. These gonoblastidia are processes from the body-wall or cœnosarc, which closely resemble true polypites in form, but differ from them in being usually devoid of a mouth, and in having shorter tentacles.

As regards the development of the *Corynida*, the embryo is very generally, though not always, ciliated at first, and becomes developed into a hydra-form polypite, which fixes itself to some foreign body, and then (if not belonging to one of the simple forms) proceeds to produce by gemmation the composite adult. The development of the *Corynida* (as well as that of the *Sertularida* and *Lucernarida*) obeys the general law that the new polypites are developed at, or near, the distal end of the hydrosoma; so that the distal polypites are the youngest, the reverse of this obtaining amongst the oceanic *Hydrozoa*.

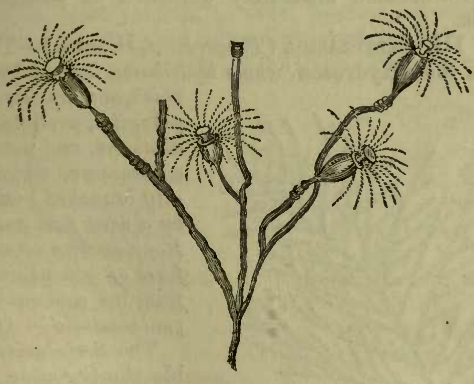


Fig. 15.—Corynida. Fragment of *Eudendrium rameum*, enlarged.

The subject of the reproduction of the *Corynida* having been treated at some length, so as to apply to the remaining *Hydroida*, we shall now give a brief description of the two leading types of structure exhibited by the order.

Eudendrium, a genus of the *Corynida*, which is not uncommonly found attached to submarine objects, usually in tolerably deep water, may be taken as a good example of the fixed and composite division of the order. The hydrosoma consists of numerous polypites, united by a cœnosarc, which is more or less branched, and is defended by a horny tubular polypary. The polypites are borne at the ends of the branches and branchlets, and are not contained in 'hydrothecæ,' the polypary ending abruptly at their bases. The polypites are non-retractile, of a reddish colour, and provided with about twenty tentacles, arranged round the mouth in a single row (*fig.* 15). *Tubularia* is very similar to *Eudendrium*, but the hydrosoma is either undivided or is very slightly branched.

Coryomorpha nutans may be taken to represent those *Corynida* in which there is no polypary and the hydrosoma is simple. It is about four inches in length, and is fixed by filamentous roots to the sand at the bottom of the sea. It consists of a single whitish polypite, striped with pink, and terminating upwards in a pear-shaped head, round the thickest part of which is a circlet of from forty to fifty long white tentacles. Above these comes a series of long branching gonoblastidia, bearing gonophores, and succeeded by a second shorter set of tentacles which surround the mouth. The gonophores become ultimately detached as free-swimming medusoids.

ORDER III. SERTULARIDA (*Thecaphora*, Hincks.)—This order comprises those Hydrozoa '*whose hydrosoma is fixed by a hydrorhiza, and consists of several polypites, protected by hydrothecæ, and connected by a cœnosarc, which is usually branched and invested by a very firm outer layer. Reproductive organs in the form of gonophores arising from the cœnosarc or from gonoblastidia.*'—(Greene.)

Fig. 16.—*Sertularia rosacea*, the lily-coralline, showing ovarian vesicles.

The *Sertularida* resemble the *Corynida* in becoming permanently fixed after their embryonic condition by a hydrorhiza, which is developed from the proximal end of the cœnosarc; but they differ in the fact that the polypites are invariably protected by 'hydrothecæ,' or little cup-like expansions of the polypary (*figs.* 17, 18); whilst the hydrosoma is in all cases composed of more than a single polypite. The cœnosarc generally consists of a main stem—or 'hydrocaulus'—with many branches; and it is so plant-like in appearance that the common Sertularians are almost always mistaken for sea-weeds by visitors at the seaside. It is invested by a strong corneous or chitinous covering, often termed the 'periderm.'

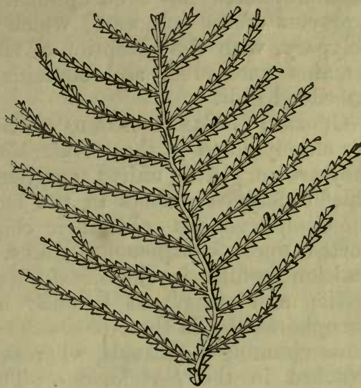


Fig. 17.—*Sertularia abietina*, the sea-fir.

The polypites are sessile or subsessile, hydra-form, and in all essential respects identical with those of the *Corynida*, though usually smaller. The tentacles are placed below the mouth, and have an indistinctly alternate arrangement. The generative buds (gonophores or ovarian vesicles) are usually supported upon gonoblastidia, and seldom, if ever, become detached in the true Sertularids. They are often developed in chitinous receptacles known as 'gonothecæ' (*fig.* 18). The young Sertularian on escaping from the ovum appears as a free-swimming ciliated body, which soon loses its cilia, fixes itself, and develops a young cœnosarc, by gemmation from which the branching hydrosoma of the perfect organism is produced.

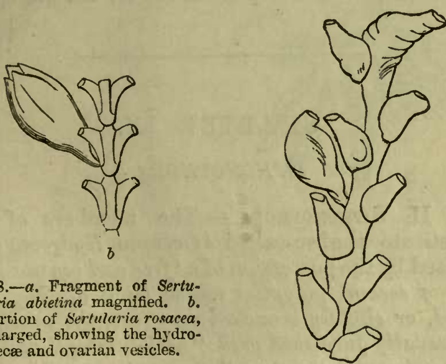


Fig. 18.—*a*. Fragment of *Sertularia abietina* magnified. *b*. Portion of *Sertularia rosacea*, enlarged, showing the hydrothecæ and ovarian vesicles.

In *Plumularia* and some of its allies there occur certain peculiar organs, probably offensive, to which the name of 'nematophores' has been applied. Each of these consists of a process of the cœnosarc, which is invested by the horny polypary, with the exception of the distal extremity, which remains uncovered, and contains many large thread-cells imbedded in it.

ORDER IV. CAMPANULARIDA.—The members of this order are closely allied to the *Sertularida*; so closely, indeed, that they are very often united together into a single group. The chief difference consists in the fact that the hydrothecæ of the *Campanularida* with their contained polypites are supported upon conspicuous stalks, thus being terminal in position; whilst in the *Sertularida* they are sessile or sub-sessile, and are placed laterally upon the branchlets. The gonophores also in the *Campanularida* are usually detached as free-swimming medusoids, whereas they remain permanently attached in the *Sertularians*. The ova in the medusiform gonophores are usually developed in the course of the gono-calycine canals, and not between the ectoderm and endoderm of the manubrium, as is the case in the *Corynida*. Examples of the order are *Campanularia*, *Laomedea*, &c. The distinctions between the *Sertularida* and *Campanularida* are certainly insufficient to justify their being placed in separate orders. If united together, it would probably be best to adopt the name *Thecaphora* (Hincks) for the order, and to employ the names *Sertularida* and *Campanularida* for the sub-orders.

CHAPTER IX.

SIPHONOPHORA.

SUB-CLASS II. SIPHONOPHORA. — The members of this sub-class constitute the so-called 'Oceanic *Hydrozoa*;' and are characterised by the possession of a '*free and oceanic hydrosoma, consisting of several polypites united by a flexible, contractile, unbranched, or slightly branched cœnosarc, the proximal end of which is usually furnished with "nectocalyces," and is dilated into a "somatocyst," or into a "pneumatophore."*'—(Greene.)

All the *Siphonophora* are unattached, and permanently free, and all are composite. They are singularly delicate organisms, mostly found at the surface of tropical seas, the Portuguese man-of-war (*Physalia*) being the most familiar member of the group. The sub-class is divided into two orders, viz. the *Calycophoridæ* and the *Physophoridæ*.

ORDER I. CALYCOPHORIDÆ. — This order includes those *Siphonophora* whose *hydrosoma is free and oceanic, and is propelled by 'nectocalyces' attached to its proximal end. The hydrosoma consists of several polypites, united by an unbranched cœnosarc, which is highly flexible and contractile, and never develops a hard cuticular layer. The proximal end of the hydrosoma is modified into a peculiar cavity called the "somatocyst." The reproductive organs are in the form of medusiform gonophores produced by budding from the peduncles of the polypites.*

In all the *Calycophoridæ* the cœnosarc is filiform, cylindrical, unbranched, and highly contractile, this last property being due to the presence of abundant muscular fibres. 'The proximal end of the cœnosarc dilates a little, and becomes ciliated internally, forming a small chamber' which communicates with the nectocalycine canals. 'At its upper end this

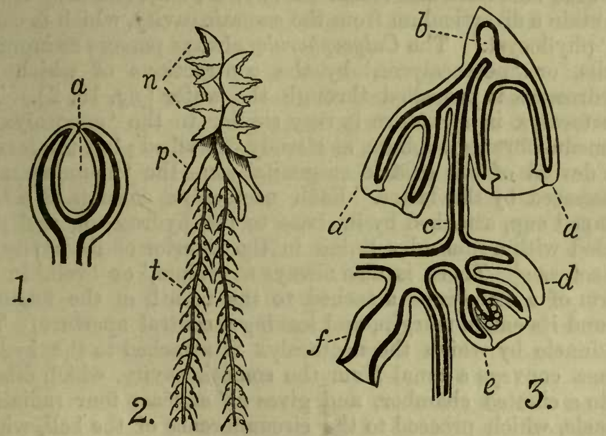


Fig. 19.—Morphology of the Oceanic Hydrozoa. 1. Diagram of the proximal extremity of a *Physophorid*. *a*. Pneumatocyst. 2. *Vogtia pentacantha*, one of the *Calycophoridæ*. *n*. Nectocalyces; *p*. Polypites; *t*. Tentacles. 3. Diagram of a *Calycophorid*. *a a'*. Proximal and distal nectocalyces; *b*. Somatocyst; *c*. Cœnosarc; *d*. Hydrophyllium or bract; *e*. Medusiform gonophore; *f*. Polypite. The dark lines in figs. 1 and 3 indicate the endoderm, the light line with the clear space indicates the ectoderm. (After Huxley.)

chamber is a little constricted, and so passes, by a more or less narrowed channel, into a variously shaped sac, whose walls are directly continuous with its own, and which will henceforward be termed the *somatocyst* (*fig.* 19, 3 *b*). The endoderm of this sac is ciliated, and it is generally so immensely vacuolated as almost to obliterate the internal cavity and give the organ the appearance of a cellular mass.'—(Huxley). The polypites in the *Calycophoridæ* often show a well-marked division into three portions, termed respectively the proximal, median, and distal divisions. Of these, the 'proximal' division is somewhat contracted, and forms a species of peduncle, which often carries appendages. The 'median' portion is the widest, and may be termed the 'gastric division,' as in it the process of digestion is carried on. It is usually separated from the proximal division by a valvular inflexion of the endoderm, which is known as the 'pyloric valve.' The polypites have only one tentacle 'developed near their basal or proximal ends, and provided with lateral branches ending in saccular cavities,' and furnished with numerous thread-cells. The proximal ends of the polypites also bear certain overlapping plates, of a protective nature, which are termed 'hydrophyllia,' or 'bracts.' They are composed of processes of both ectoderm and endoderm (*fig.* 19, 3 *d*), and they always contain a diverticulum from the somatic cavity, which is called a 'phyllocyst.' The *Calycophoridæ* always possess swimming-bells, or 'nectocalyces,' by the contractions of which the hydrosoma is propelled through the water (*fig.* 19, 2). The nectocalyx in structure is very similar to the 'gonocalyx' of a medusiform gonophore, as already described; but the former is devoid of the gastric or genital sac—the 'manubrium'—possessed by the latter. Each nectocalyx consists of a bell-shaped cup, attached by its base to the hydrosoma, and provided with a muscular lining in the interior of its cavity, or 'nectosac.' There is also always a 'velum,' or 'veil,' in the form of a membrane attached to the mouth of the nectosac round its entire margin, and leaving a central aperture. The peduncle by which the nectocalyx is attached to the hydrosoma conveys a canal from the somatic cavity, which dilates into a ciliated chamber, and gives off at least four radiating canals, which proceed to the circumference of the bell, where they are united by a circular vessel; the entire system constituting what is known as the system of the 'nectocalycine canals.' In the typical *Calycophoridæ* two nectocalyces only are present, but in some genera there are more. In *Praya* the two nectocalyces are so apposed to one another that a sort of canal is formed by the union of two grooves, one of which exists on the side of each nectocalyx. This chamber, which is present in a more or less complete form in all the genera, is termed the 'hydrœcium,' and the cœnosarc can be retracted within it for protection.

The reproductive bodies in the *Calycophoridæ* are in the form of medusiform gonophores, which are budded from the peduncles of the polypites, becoming, in many instances, detached to lead an independent existence. In some *Calycophoridæ*, as in *Abyla*, 'each segment of the cœnosarc, provided with a polypite, its tentacle, reproductive organ, and hydrophyllium, as it acquires a certain size, becomes detached, and leads an independent life—the calyx of its reproductive organ serving it as a propulsive apparatus. In this condition it may acquire two or three times the dimensions it had when detached, and some of its parts may become wonderfully altered in form.'—(Huxley.) To these detached reproductive portions of adult *Calycophoridæ* the term 'Diphyozoöids' has been applied.

As regards the development of the *Calycophoridæ*, 'not only the new polypites, but the new nectocalyces and reproductive organs, and even the branches of the tentacles, are developed on the proximal side of the old ones; so that the distal appendages are the oldest.'—(Huxley.) The process of development is, therefore, the reverse of what obtains amongst the *Hydroida*.

Diphyes, which may be taken as the type of the *Calycophoridæ*, consists of a delicate filiform cœnosarc, provided proximally with two large mitre-shaped nectocalyces, of which one lies entirely on the distal side of the other. The pointed apex of the distal nectocalyx is received into a special cavity in the proximal nectocalyx. The 'hydrœcium' is formed partially by this chamber in the nectocalyx, and partially by an arched groove prolonged upon the inner surface of the distal nectocalyx, within which the cœnosarc moves freely up and down, and can be entirely retracted if necessary. The upper part of the cœnosarc dilates into a small ciliated cavity, from which are given off two tubes, which proceed respectively to the distal and proximal nectocalyces, where they open into the central chamber from which the nectocalycine canals take their rise. The upper portion of this small ciliated cavity is prolonged proximally into the larger chamber of the 'somatocyst.' The cœnosarc bears polypites, each of which is protected by a delicate glassy 'hydrophyllium.'

DIVISIONS OF THE CALYCOPHORIDÆ.—(AFTER HUXLEY.)

Fam. I. *Diphydæ.*—Nectocalyces not more than two in number, and of a polygonal shape. Hydrœcium of the proximal nectocalyx complete, or closed posteriorly. Hydrophyllia well developed.

Fam. II. *Sphæronectidæ.*—Nectocalyces probably not more than two in number; the proximal nectocalyx spheroidal, with a complete hydrœcium. No hydrophyllia (?).

Fam. III. *Prayidæ.*—Nectocalyces two in number; hydrœcia incomplete and groove-like. Polypites protected by hydrophyllia.

Fam. IV. *Hippopodidæ.*—Nectocalyces numerous; hydrœcia incomplete. Polypites not protected by hydrophyllia.

ORDER II. PHYSOPHORIDÆ.—This second order of the *Oceanic Hydrozoa* comprises those *Siphonophora, in which the hydrosoma consists of several polypites united by a flexible, contractile, unbranched or very slightly branched cœnosarc, the proximal extremity of which is modified into a 'pneumatophore,' and is sometimes provided with 'nectocalyces.' The polypites have either a single basal tentacle, or the tentacles arise directly from the cœnosarc. 'Hydrophyllia' are commonly present. The reproductive organs are developed upon gonoblastidia.*

The cœnosarc in the *Physophoridæ*, like that of the *Calycophoridæ*, is perfectly flexible and contractile; but it is not necessarily elongated, being sometimes spheroidal or discoidal. The proximal end of the cœnosarc 'expands into a variously shaped enlargement, whose walls consist of both ectoderm and endoderm, and which encloses a wide cavity in free communication with that of the cœnosarc, and, like it, full of the nutritive fluid. From the distal end, or apex, of this cavity depends a sac, variously shaped, but always with tough, strong, and elastic walls, composed of a substance which is stated to be similar to chitine in composition, and more or less completely filled with air.'—(Huxley.) The large proximal dilatation of the cœnosarc is termed the 'pneumatophore,' whilst the chitinous air-sac which it contains is termed the 'pneumatocyst' (*fig.* 19, 1). The pneumatocyst is held in position by the reflection of the endoderm of the pneumatophore over it, and it doubtless acts as a buoy or 'float.' In the Portuguese man-of-war (*Physalia*) the pneumatocyst communicates with the exterior by means of an aperture in the ectoderm of the pneumatophore. In *Velella* and *Porpita* the pneumatocyst communicates with the exterior by means of several openings called 'stigmata;' and from its distal surface depend numerous slender processes, containing air, and known as 'pneumatic filaments.'

The polypites of the *Physophoridæ* resemble those of the *Calycophoridæ* in shape, but the tentacles have a much more complicated structure, and are sometimes many feet in length, as in *Physalia*. The 'hydrophyllia' have essentially the same structure as those of the former order. There occur also in the *Physophoridæ* certain peculiar bodies, termed 'hydrocysts' or 'feelers' ('fühler' and 'taster' of the Germans). These resemble immature polypites in shape, consisting of a prolongation of both ectoderm and endoderm, usually with a tentacle, and containing a diverticulum of the somatic cavity, the distal extremity being closed, and furnished with numerous large thread-cells. They are looked upon as 'organs of prehension and touch,' and they are somewhat analogous to the 'nematophores' of some of the *Sertularida.*

As regards the reproductive organs, they are developed upon special processes or 'gonoblastidia,' and they may remain permanently attached, or they may be thrown off as free-swimming medusoids. In many of the *Physophoridæ* the male and female gonophores differ from one another in form and size, and they are then termed respectively 'androphores' and 'gynophores.' As regards their development the *Physophoridæ* obey the same general law as the *Calycophoridæ.*

In *Physophora* the hydrosoma consists of a filiform cœnosarc, which bears the polypites and their appendages, and dilates proximally into a pneumatophore. Below this point the cœnosarc bears a double row of nectocalyces, which are channelled on their inner faces to allow of their attachment to the cœnosarc. There are no hydrophyllia, but there is a series of 'hydrocysts' on the proximal side of the polypites.

Physalia, or the Portuguese man-of-war, is composed of a large, bladder-like, fusiform 'float' or pneumatophore — sometimes from eight to nine inches in length—upon the under surface of which are arranged a number of polypites, together with highly contractile tentacles of great length, 'hydrocysts,' and reproductive organs. *Physalia* is of common occurrence, floating at the surface of tropical seas.

In *Velella* the hydrosoma consists of a widely expanded pneumatophore of a rhomboidal shape, carrying upon its upper surface a diagonal vertical crest. Both the horizontal disc and the vertical crest are composed of a soft marginal 'limb,' and a central more consistent 'firm part.' 'To the distal surface of the firm part of the disc are attached the several appendages, including, 1. a single large polypite, nearly central in position; 2. numerous small gonoblastidia, which resemble polypites, and are termed "phyogemmaria;" and 3. the reproductive bodies to which these last give rise. The tentacles are attached, quite independently of the polypites, in a single series along the line where the firm part and limb of the disc unite. There are no hydrocysts, nectocalyces, or hydrophyllia. . . . . . . On all sides the limb is traversed by an anastomosing system of canals, which are ciliated, and communicate with the cavities of the phyogemmaria and large central polypite.'—(Greene.) *Velella* is about two inches in length by one and a half in height. It is of a beautiful blue colour and semi-transparent, and it floats at the surface of the sea, with its vertical crest exposed to the wind as a sail.

DIVISIONS OF PHYSOPHORIDÆ.—(AFTER HUXLEY.)

Fam. I. *Apolemiadæ.*—Hydrosoma with nectocalyces and hydrophyllia, the latter united with the other organs into groups, which are arranged at considerable intervals along the cœnosarc. Cœnosarc filiform. Pneumatocyst small.

Fam. II. *Stephanomiadæ.*— Hydrosoma with nectocalyces and hydrophyllia, the latter arranged with the other organs in a continuous series. Cœnosarc filiform. Pneumatocyst small.

Fam. III. *Physophoridæ.*—Hydrosoma with nectocalyces, but without hydrophyllia. Distal end of the filiform cœnosarc dilated. Pneumatocyst small.

Fam. IV. *Athorybidæ.*—Hydrosoma without nectocalyces, but with hydrophyllia. Pneumatocyst occupying almost the whole of the globular cœnosarc.

Fam. V. *Rhizophysiadæ.*—Hydrosoma without either nectocalyces or hydrophyllia. Cœnosarc filiform. Pneumatocyst small.

Fam. VI. *Physaliadæ.*—Pneumatocyst occupying almost the whole of the thick and irregularly fusiform cœnosarc. No nectocalyces or hydrophyllia.

Fam. VII. *Velellidæ.*—Hydrosoma without nectocalyces or hydrophyllia; with short, simple, or branched, submarginal tentacles. A single central principal polypite. Pneumatocyst flattened, divided into chambers by numerous concentric partitions, and occupying almost the whole of the discoidal cœnosarc.

CHAPTER X.

DISCOPHORA.

SUB-CLASS III. DISCOPHORA (*Acalephæ* * in part).— Since this sub-class contains only a single order, that of the *Medusidæ*, a single definition necessarily suffices for both. The *Medusidæ* are defined as '*Hydrozoa whose hydrosoma is free and oceanic, consisting of a single nectocalyx, from the roof of which a single polypite is suspended. The nectocalyx is furnished with a system of canals. The reproductive organs are as processes either of the sides of the polypite or of the nectocalycine canals.*'—(Greene.)

* The old sub-class of the *Acalephæ* contained the *Gymnophthalmate Medusæ* (= the *Discophora*), and the *Steganophthalmate Medusæ* (= the *Lucernarida* in part), the two being placed in a single order under the name of *Pulmograda*. The *Acalephæ* also contained the *Ctenophora* and the *Calycophoridæ* and *Physophoridæ*, of which the former constituted the order *Ciliograda*, whilst the two latter made up the order *Physograda*. The *Ctenophora*, however, are now generally placed amongst the *Actinozoa*, whilst the *Calycophoridæ* and *Physophoridæ* constitute the Hydrozoal sub-class *Siphonophora*.

The *Medusidæ* comprise most of the organisms commonly known as Jelly-fishes or Sea-nettles, the last name being derived from the property which many of them possess of severely stinging the hand, this power being due to the presence of numerous thread-cells. As employed by modern naturalists, the order is very much restricted, and it is by no means improbable that it will ultimately be entirely done away with, very many of its members having been shown to be really the free generative buds of other *Hydrozoa*. As used here, it corresponds to part of the *Gymnophthalmate Medusæ* of Professor E. Forbes, the *Steganophthalmate Medusæ* of the same author being now placed in the sub-class *Lucernarida*.

The hydrosoma of one of the *Discophora* (= a Gymnophthalmate *Medusa*) is composed of a single gelatinous bell-shaped swimming organ, the 'nectocalyx' or 'disc,' from the roof of which a single polypite is suspended (*fig.* 20). The in-

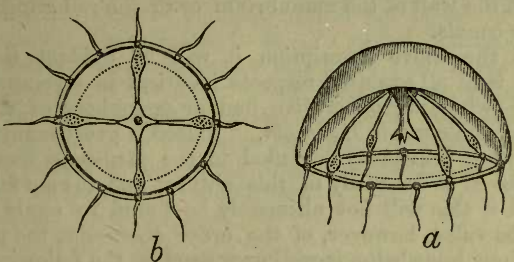


Fig. 20.—Morphology of Medusidæ. *a.* A medusid (*Thaumantias*) seen in profile, showing the central polypite, the radiating and circular gonocalycine canals, the marginal vesicles and tentacles, and the reproductive organs. *b.* The same viewed from below. The dotted line indicates the margin of the velum.

terior of the nectocalyx is often called the 'nectosac,' and the term 'codonostoma' has been proposed to designate the open mouth of the bell. The margin of the nectocalyx is produced inwards to form a species of shelf, running round the margin of the mouth of the bell, and termed the 'veil' or 'velum,' by the presence of which the nectocalyx is distinguished from the somewhat similar 'umbrella' of the *Lucernarida*. The endodermal lining of the central polypite or 'manubrium' (sometimes called the 'proboscis) is prolonged into four radiating canals, which run to the periphery of the nectocalyx, where they are connected by a circular canal which runs round its circumference, the whole constituting the system of the 'nectocalycine canals' (formerly called the 'chylaqueous canals'). From the circumference of the nectocalyx depend marginal tentacles, which are usually hollow processes, composed of both ectoderm and endoderm, and in immediate connection with the canal system. Also round the circumference of the nectocalyx are disposed certain 'marginal bodies,' of which two kinds may be distinguished. Of these the first are termed 'vesicles,' and consist of rounded sacs lined by epithelium, and containing one or more solid, motionless concretions — apparently of carbonate of lime — immersed in a transparent fluid. The second class of marginal bodies, variously termed 'pigment spots,' 'eye-specks,' or 'ocelli,' consists of little aggregations of pigment enclosed in distinct cavities. The 'vesicles' are probably rudimentary organs of hearing, and possibly the eye-specks are a rudimentary form of visual apparatus. The oral margin of the polypite may be simple, or it may be produced into lobes, which are most frequently four in number. The essential elements of generation are produced in simple expansions either of the wall of the manubrium or of the radiating nectocalycine canals.

From the above description it will be evident that the *Medusa* is in all essential respects identical in structure with the free-swimming generative bud or gonophore of many of the fixed and oceanic *Hydrozoa*. Indeed, a great many forms which were previously included in the *Medusidæ* have now been proved to be really of this nature, and it may fairly be doubted if this will not ultimately be found to apply to all. As to the value, however, of the order *Medusidæ*, the present state of our knowledge is well expressed by the following conclusions which have been drawn up by Professor Greene:—

'1. That several of the organisms formerly described as *Medusidæ* are the free gonophores of other orders of *Hydrozoa*.

'2. That the homology of these free gonophores with those simple expansions of the body-wall which in *Hydra* and some other genera are known to be reproductive organs by their contents alone, is proved alike by the existence of numerous transitional forms and by an appeal to the phenomena of their development.

'3. That many of the so-called *Medusidæ* may, from analogy, be regarded as, in like manner, medusiform gonophores.

'4. But that there may exist, nevertheless, a group of *Medusid* forms, which may give rise by true reproduction to organisms directly resembling their parents, and therefore worthy of being placed in a separate order under the name *Medusidæ*.'

The same authority concludes by remarking that to the order, as above defined, 'may be referred provisionally that large assemblage of forms anatomically similar to true *Medusidæ*, but whose development is unknown.' Besides the large group of forms thus temporarily admitted, all the *Trachynemidæ* and *Æginidæ* are stated by Gegenbauer to fulfil the conditions of the above definition, and should, therefore, be looked upon as true *Medusidæ*.

As to the development of these true *Medusidæ*, little is known for certain. It appears, however, that in *Trachynema*, *Æginopsis* and other genera the embryo is directly developed into a form resembling its parent, without passing through any intermediate changes of form. It is hardly necessary to remark that this is not the case with the embryos of a medusiform gonophore, these being developed into the sexless *Hydrozoön* by which the medusoid was produced.

In this connection, allusion may be made to the long-known fact that certain medusiform gonophores *are* capable of producing independent forms directly resembling themselves, but this is by a process of gemmation and not by one of true reproduction. Technically these are called 'tritozoöids,' as being derived from organisms which are themselves but the generative zoöids of another being. This singular phenomenon has been observed in various medusiform gonophores (e.g. *Sarsia gemmifera*), the buds springing in different species from the gonocalycine canals, from the tentacles, or from the sides of the polypite or manubrium.

CHAPTER XI.

LUCERNARIDA AND GRAPTOLITIDÆ.

SUB-CLASS IV. LUCERNARIDA (*Acalephæ*, in part).—The members of this sub-class may be defined as *Hydrozoa*, '*whose hydrosoma has its base developed into an "umbrella," in the walls of which the reproductive organs are produced.*'—(Greene.)

A large number of forms included in the *Lucernarida* were described by Edward Forbes under the name of *Steganophthalmate Medusæ*, being in many external characters closely similar to the *Medusidæ*. This resemblance is especially strong between the disc or 'nectocalyx' of the true *Medusidæ* and the 'umbrella' of the *Lucernarida*, the latter being often a bell-shaped swimming organ, with marginal tentacles, and containing one or more polypites. These analogous structures (*figs.* 20 and 23) are, however, distinguished as follows:—

1. The 'umbrella' of the *Lucernarida* is never furnished with a 'velum,' as is the nectocalyx of the *Medusidæ*. 2. The radiating canals in the former are never less than eight in number, and they send off numerous anastomosing branches, which join to form an intricate network; whereas in the latter they are not more than four in number, and they do not subdivide. 3. In the place of the separate and unprotected 'vesicles' and 'ocelli' of the *Medusidæ*, the marginal bodies of the *Lucernarida* consist of these bodies combined together into single organs, which are termed 'lithocysts,' and which are protected externally by a sort of hood.

The *Lucernarida* admit of being divided into three orders, viz.:—the *Lucernariadæ*, the *Pelagidæ*, and the *Rhizostomidæ*.

ORDER I. LUCERNARIADÆ.—This order includes those *Lucernarida which have only a single polypite, are fixed by a proximal hydrorhiza, and possess short tentacles on the margin of the umbrella. The reproductive elements* '*are developed in the primitive hydrosoma without the intervention of free zoöids.*' —(Greene.)

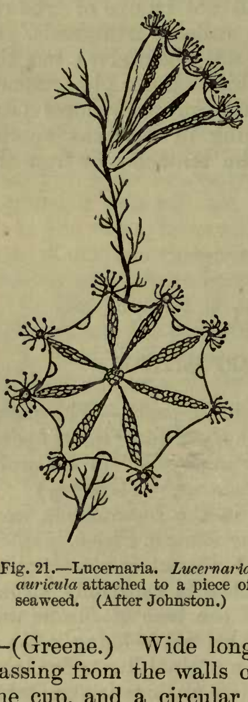


Fig. 21.—Lucernaria. *Lucernaria auricula* attached to a piece of seaweed. (After Johnston.)

In *Lucernaria* (*fig.* 21), which may be taken as the type of the order, the body is campanulate or cup-shaped, and is attached proximally at its smaller extremity by a hydrorhiza, which, however, like that of the *Hydra*, is not permanently fixed. When detached, the animal is able to swim with tolerable rapidity by means of the alternate contraction and expansion of the umbrella. Around the margin of the umbrella are tufts of short tentacular processes, and in its centre is a polypite with a quadrangular, four-lobed mouth. 'In transverse section the polypite may be described as somewhat quadrilateral, with a sinuous outline, which expands at its four angles to form as many deep longitudinal folds, within which the simple generative bands are lodged.' —(Greene.) Wide longitudinal canals are formed by septa passing from the walls of the polypite to the inner surface of the cup, and a circular canal runs immediately beneath the insertion of the tentacles. The reproductive elements are produced within the body of *Lucernaria* itself, without the intervention of any generative zoöid.

ORDER II. PELAGIDÆ.—This order is defined as including *Lucernarida, which possess a single polypite only and an umbrella with marginal tentacles. The reproductive elements 'are developed in a free umbrella, which either constitutes the primitive hydrosoma, or is produced by fission from an attached Lucernaroid.'*—(Greene.)

Two types, therefore, exist in the *Pelagidæ.* The one type is represented by a fixed 'trophosome,' resembling *Lucernaria*, but distinguished from it by the fact that the generative elements are not developed in the primitive hydrosoma, but in a free 'gonosome,' which is produced for the purpose. The second type, represented by *Pelagia* itself, is permanently free, thereby differing from *Lucernaria*, which it approaches, on the other hand, in the fact that its generative elements are produced in its own umbrella without the intervention of free generative zoöids. *Pelagia*, however, differs considerably in structure from *Lucernaria*, and in all essential characters is not anatomically separable from a *Steganophthalmate Medusid.* The process of reproduction as displayed in the first section of the *Pelagidæ* will be considered when treating of that of the *Rhizostomidæ*, there being no important difference between the two, except as concerns the structure of the generative zoöids.

ORDER III. RHIZOSTOMIDÆ.—The members of this order are defined as being *Lucernarida*, in which *the reproductive elements are developed in free zoöids, produced by fission from attached Lucernaroids. The umbrella of the generative zoöids is without marginal tentacles, and the polypites are 'numerous, modified, forming with the genitalia a dendriform mass depending from the umbrella.'*—(Greene.)

The following is a brief summary of the life-history of a member of this extraordinary order (*fig.* 22). The embryo is a free-swimming, oblong, ciliated body, termed a 'planula' (*a*), of a very minute size, and composed of an outer and inner layer enclosing a central cavity. The planula soon becomes pear-shaped, and a depression is formed at its larger end. 'Next, the narrower end attaches itself to some submarine body, whilst the depression at the opposite extremity becoming deeper and deeper at length communicates with the interior cavity. Thus, a mouth is formed, around which may be seen four small protuberances, the rudiments of tentacula. In the interspaces of these four new tentacles arise; others in quick succession make their appearance, until a circlet of numerous filiform appendages, containing thread-cells, surrounds the distal margin of the "Hydra-tuba" (*b*), as the young organism at this stage of its career has been termed by Sir J. G. Dalyell. The mouth, in the meantime, from being a mere quadrilateral orifice, grows and lengthens itself so as to constitute a true polypite, occupying the axis of the inverted umbrella, or disc, which supports the marginal tentacles. The space between the walls of the polypite and umbrella is divided into longitudinal canals, whose relations to the rest of the organism, and, indeed, the whole structure of *Hydra-tuba*, closely resemble what may be seen in *Lucernaria*.'—(Greene, *Manual of Cœlenterata*.) The *Hydra-tuba* thus constitutes the fixed 'Lucernaroid,' or the 'trophosome' of one of the *Rhizostomidæ*. In height it is less than half an inch, but it possesses the power of forming, by gemmation, large colonies, which may remain in this condition for years, the organism itself being incapable of producing the essential elements of generation. Under certain circumstances, however, reproductive zoöids are produced by the following singular process (*fig*. 22). The *Hydra-*

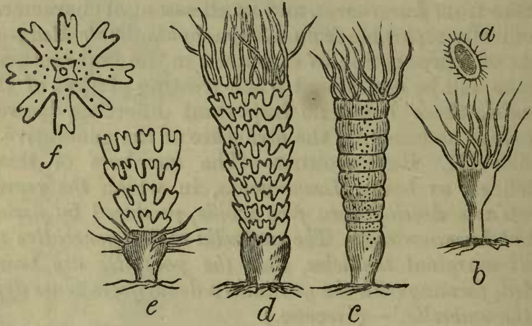


Fig. 22.—Development of Lucernarida (*Chrysaora*). *a*. Ciliated ovum or 'planula.' *b*. Hydra-tuba. *c*. Hydra-tuba undergoing fission or 'Scyphistoma.' *d*. The fission still further advanced, constituting the 'Strobila.' *e*. A form still further advanced, in which a fresh circlet of tentacles has been developed near the base. *f*. Free-swimming medusoid or 'Ephyra,' produced by fission from the hydra-tuba.

tuba becomes elongated, and becomes marked by a series of grooves or circular indentations, extending transversely across the body from a little below the tentacles to a little above the fixed extremity. At this stage the organism was described as new by Sars, under the name '*Scyphistoma*' (*c*). The annulations or constrictions go on deepening, and become lobed at their margin, till the *Scyphistoma* assumes the aspect of a pile of saucers, arranged one upon another with their concave surfaces upwards. This stage was described by Sars under the name of '*Strobila*' (*d*). The tentacular fringe which originally surrounded the margin of the *Hydra-tuba* now disappears, and a new circlet is developed below the annulations, at a point a little above the fixed extremity of the *Strobila* (*e*). 'The disc-like segments above the tentacles gradually fall off, and, swimming freely by the contractions of the lobed margin which each presents, they have been described by Eschscholtz as true *Medusidæ* under the name of *Ephyræ*' (*f*). Each *Ephyra*, however, soon shows its true nature by becoming developed into a free-swimming reproductive body, usually of large size, with umbrella, hooded lithocysts and tentacles, constituting, in fact, a *Steganophthalmate Medusa*. The reproductive zoöid now swims freely by the contractions of its umbrella, and it eats voraciously and increases largely in size. The essential elements of generation are then developed in special cavities in the umbrella, and the fertilised ova, when liberated, appear as free-swimming, ciliated 'planulæ,' which fix themselves, become *Hydra-tubæ*, and commence again the cycle of phenomena which we have above described.

As regards the *size* of these reproductive zoöids as compared with the organism by which they are given off, it may be mentioned that the umbrella of *Cyanea arctica* has been found in one specimen to be seven feet in diameter, with tentacles more than fifty feet in length, the fixed *Lucernaroid* from which it was produced not being more than half an inch in height.

As regards the special structure of these gigantic reproductive bodies, considerable differences obtain between the *Rhizostomidæ* and that section of the *Pelagidæ*, in which this method of reproduction is employed. In the *Pelagidæ*, namely, the generative zoöids possess a general, though chiefly mimetic, resemblance both to the genuine *Discophora* and to the free-swimming medusiform gonophores of so many of the *Hydrozoa*, and they have the following structure. Each consists of a bell-shaped, gelatinous disc, the 'umbrella,' from the roof of which is suspended a large polypite, the lips of which are extended into lobed processes often of considerable length, 'the folds of which serve as temporary receptacles for the ova in the earlier stages of their development.' The polypite—manubrium or proboscis—is hollowed into a digestive sac, which communicates with a cavity in the roof of the umbrella from which arise a series of radiating canals, the so-called 'chylaqueous canals.' These canals, which are never less than eight in number, branch freely and anastomose as they pass towards the periphery of the umbrella, where the entire series is connected by a circular marginal canal. This, in turn, sends tubular processes into the marginal tentacles, which are often of great length. Besides the tentacles, the margin of the umbrella is furnished with a series of peculiar bodies, termed 'lithocysts,' each of which is protected by a sort of process or hood derived from the ectoderm, and consists essentially of a combined 'vesicle' and 'pigment-spot,' such as have been described as occurring in the *Medusidæ*. These marginal bodies likewise communicate with the chylaqueous canals. The reproductive elements 'are lodged in saccular processes of the lower portion of the central cavity, immediately above the bases of the radiating canals, and, being

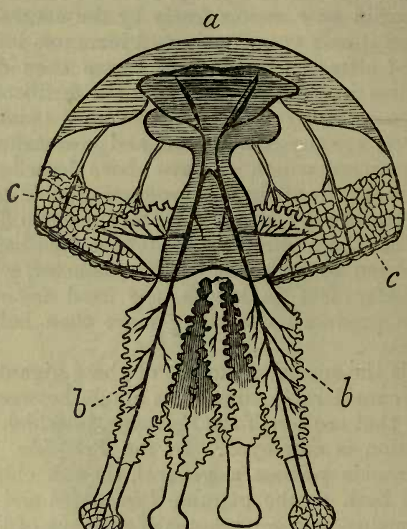


Fig. 23.—Rhizostomidæ. Generative zoöid of *Rhizostoma*. (After Owen.) *a*. Umbrella. *b b*. 'Stomatodendra,' covered with clavate tentacles and minute polypites. *c c*. Anastomosing network of canals.

usually of some bright colour, form a conspicuous cross shining through the thickness of the disc.'—(Greene.)

In the *Rhizostomidæ* the reproductive zoöids differ from those we have just described as occurring in the first section of the *Pelagidæ*, in not possessing tentacles on the margin of the umbrella, and in having the simple central polypite replaced by a composite dendriform process, which bears numerous polypites, projects far below the umbrella, and is thus described by Professor Huxley:—'In the *Rhizostomidæ* (*fig*. 22) a complex, tree-like mass, whose branches, the "stomatodendra," end in, and are covered by, minute polypites, interspersed with clavate tentacula, is suspended from the middle of the umbrella in a very singular way. The main trunks of the dependent polypiferous tree, in fact, unite above into a thick, flat, quadrate disc, the "syndendrium," which is suspended by four stout pillars, the "dendrostyles," one springing from each angle, to four corresponding points on the under surface of the umbrella, equidistant from its centre. Under the middle of the umbrella, therefore, is a chamber, whose floor is formed by the quadrate disc, whilst its roof is constituted by the under wall of the central cavity of the umbrella, and its sides are open. The reproductive elements are developed within radiating folded diverticula of the roof of this genital cavity.'

It appears, finally, that amongst the old Pulmograde Acalephæ, or amongst what would commonly be called Jelly-fishes, we have the following distinct sets of beings, which resemble each other more or less closely in appearance, but differ in their true nature :—

1. Free medusiform gonophores of various *Corynidæ*, *Sertularidæ*, *Campanularidæ*, and the *Oceanic Hydrozoa.*

2. True *Medusidæ*, entirely resembling the former in anatomical structure, but differing in the fact that their ova do not give rise to a fixed zoöid, but to free-swimming organisms exactly like the parent hydrosoma (*Trachynemidæ* and *Æginidæ*).

3. *Hydrozoa* which are provided with an 'umbrella' (with all the peculiarities belonging to this structure), but which reproduce themselves without the intervention of free generative zoöids produced by fission (*Pelagia*).

4. The free generative zoöids of most of the *Pelagidæ*, with an umbrella and a single polypite, the primitive hydrosoma being fixed and sexless (*Aurelia*, *Cyanea*, &c.).

5. The free generative zoöids of the *Rhizostomidæ*, with an umbrella and a complex central tree bearing many polypites (*Rhizostoma*, *Cephea*, &c.).

Of these five classes of organisms, Nos. 1 and 2 constitute the Gymnophthalmate *Medusæ* of Professor E. Forbes, whilst Nos. 3, 4 and 5 are the Steganophthalmate *Medusæ* of the same naturalist.

SUB-CLASS V. GRAPTOLITIDÆ.—The organisms included at present under this head are all extinct, and they are in many respects so dissimilar, and their structure is so far from being entirely understood, that it is doubtful if any definition can be framed which will include *all* the supposed members of the family. The following definition, however, will include all the most typical Graptolites :—

Hydrosoma compound, occasionally branched, consisting of numerous polypites united by a cœnosarc; the latter being enclosed in a strong tubular polypary, whilst the former were protected by hydrothecæ. In the great majority of Graptolites the hydrosoma was certainly unattached, but in some aberrant forms—doubtfully belonging to the sub-class—there is reason to believe that the hydrosoma was fixed. The polypites are never separated from the cœnosarc by any partition. In many cases the hydrosoma was strengthened by a solid chitinous rod, the 'solid axis,' somewhat analogous to the chitinous rod recently described by Professor Allman in the singular Polyzoon, *Rhabdopleura*.

From the above definition, it will be seen that the nearest living allies to the Graptolites are the Sertularians. In point of fact, if we do not insist upon the presence of a 'solid axis' as part of the definition, the Graptolites differ from the Sertularians in no essential point, save that the hydrosoma is always attached in the latter, and was certainly free in the most typical examples of the former. Indeed, certain forms at present placed amongst the *Graptolites*—such as *Ptilograpsus* and *Dendrograpsus*—are so similar to some living Sertularians, that it might be well to remove them altogether from the *Graptolitidæ*, and to regard them as extinct representatives of the *Sertularidæ*.

As regards the value of the 'solid axis' as an element in defining Graptolites, we fear that much stress cannot be laid upon its presence or absence. It is true that it is present in all the most characteristic members of the sub-class, but it seems to be certainly absent in some—e.g. in *Retiolites Geinitzianus*, and in all species of *Rastrites*—and there do not seem to be sufficient grounds for excluding these from the *Graptolitidæ* on this account alone.

Taking such a simple Graptolite as *G. sagittarius* (*fig.* 24, 1) as the type of the sub-class, the hydrosoma is found to consist of the 'solid axis,' the 'common canal,' and the 'cellules.' The entire polypary is corneous and flexible, and the solid axis is a cylindrical fibrous rod, which gives support to the entire organism, and is often prolonged beyond one or both ends of the hydrosoma. The common canal is a tube which encloses the cœnosarc, and gives origin to a series of cellules, these being little cups corresponding to 'hydrothecæ,' and enclosing the polypites. Not only are the essential details of the structure—with the exception of the solid axis—strictly comparable with that of a Sertularian, but there is good evidence, as shown by Hall and the author, that the reproductive process was also carried on in a manner similar to what we have seen in the other *Hydroida*, namely, by generative buds or gonophores.

No *Graptolite*, however, has hitherto been certainly proved to have been fixed by a 'hydrorhiza,' and it is only in certain aberrant forms that there are any traces of a 'hydrocaulus.'

Besides the simple forms of Graptolites with a row of cellules on one side (monoprionidian) (*fig.* 24, 2), there are others with a row of cellules on each side (diprionidian) (*fig.* 24, 3). Many other curious modifications are known; but there is only another peculiarity which is worthy of notice here. This is the occurrence in several genera of a basal corneous disc or cup, which is probably the homologue of the 'float' or 'pneumatophore' of the Physophoridæ. (For distribution of Graptolites see Distribution of Hydrozoa in Time.)

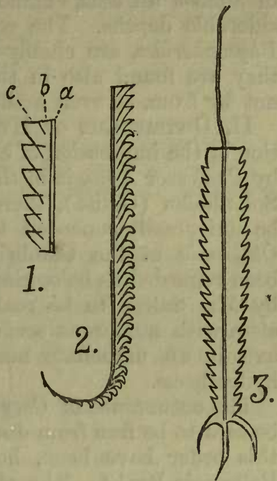


Fig. 24.—Morphology of Graptolites. 1. Portion of *Graptolites sagittarius* enlarged; *a*. Solid axis; *b*. Common canal; *c*. Cellules. 2. Monoprionidian Graptolite (*G. argenteus*). 3. Diprionidian Graptolite (*Diplograpsus pristis*, variety with long basal spines).

As regards their mode of occurrence, Graptolites are usually found as glistening, pyritous impressions, with a silvery lustre. In some cases, however, they are found in relief.

CHAPTER XII.

DISTRIBUTION OF THE HYDROZOA.

I. Distribution of Hydrozoa in Space.—The genera of *Hydrozoa* have a wide distribution, the mode of reproduction amongst the fixed forms being such as to insure their extension over considerable areas. The various species of *Hydra* are of common occurrence in the fresh waters of Europe. *Cordylophora*, the sole remaining fresh-water genus, has not been found to occur out of the north temperate zone. All the other *Hydrozoa*, without a known exception, are marine in their habits. The fixed forms, viz. the *Corynidæ*, *Sertularidæ*, and *Campanularidæ*, are represented more or less abundantly in almost all seas, extending from the littoral zone to considerable depths. The oceanic *Hydrozoa*, *Calycophoridæ* and *Physophoridæ*, are chiefly characteristic of tropical seas; but they are found also in the Mediterranean, and even in seas not far from, or even within, the Arctic circle.

II. Distribution of Hydrozoa in Time.—With the exception of the impression of a *Medusa* said to have been observed by Professor Agassiz in the fine-grained lithographic slate of Solenhofen (Oolite), there are no fossil remains which would be universally conceded to be of a *Hydrozoal* nature. The *Oldhamia* of the Cambrian Rocks of Ireland has, indeed, been regarded as belonging to the *Hydrozoa*; but it is believed by Mr. Salter to be really a plant. It consists of a main stem with numerous secondary branches, springing from the axis in an umbellate manner, but exhibiting no traces of hydrothecæ.

The occurrence of *Corynida* in a fossil condition can hardly be said to be free from doubt. Remains probably referable to this order have been, however, recently discovered in the Palæozoic Rocks. The oldest of these was described by the author some years ago from the Lower Silurian Rocks of Dumfriesshire under the name of *Corynoides.* More lately a form called *Palæocoryne* has been described from the Carboniferous Rocks of Scotland.

The *Sertularida* and *Campanularida* are not certainly known to occur in a fossil condition. The fossils called *Dendrograpsus*, *Callograpsus*, *Ptilograpsus*, and *Dictyonema*, all at present placed amongst the *Graptolites*, are, however, not improbably truly referable to the *Sertularida.*

There can be little doubt but that the large and singular family of the *Graptolitidæ* should really be looked upon as extinct *Hydrozoa*, though good authorities still place them amongst the *Polyzoa.* As regards their distribution two facts are chiefly noticeable. In the first place, no Graptolite, except the doubtful genus *Dictyonema*, has hitherto been found to occur above the Silurian Rocks. The Graptolites may therefore be regarded as characteristic fossils of the Silurian period. Secondly, the diprionidian Graptolites, or those with a row of cellules on each side (genera *Diplograpsus*, *Climacograpsus*, and *Dicranograpsus*), have never yet been certainly shown to occur above the horizon of the *Lower* Silurian Rocks. The common genus *Didymograpsus* (the 'twin' Graptolites) is still more characteristic of the Lower Silurian period.

CHAPTER XIII.

ACTINOZOA.

1. General Characters of the Actinozoa. 2. Characters of the Zoantharia. 3. Zoantharia Malacodermata. 4. Zoantharia Sclerobasica. 5. Zoantharia Sclerodermata.

Class II. Actinozoa. — The *Actinozoa* are defined as *Cœlenterata with a differentiated digestive sac opening below into the somatic cavity, but separated from it by an intervening 'perivisceral space,' which is divided into a series of compartments by vertical partitions, or 'mesenteries,' to the faces of which the reproductive organs are attached.*

The *Actinozoa* (*fig.* 25), therefore, differ fundamentally from the *Hydrozoa* in this, that whereas in the latter the digestive cavity is identical with the somatic cavity, in the former there is a distinct digestive sac, which opens, indeed, into the somatic cavity, but is, nevertheless, separated from it by an intervening perivisceral space. As a result of this, the body of a typical *Actinozoön* exhibits on transverse section two concentric tubes, one formed by the digestive sac, the other by the parietes of the body; whereas the transverse section of a *Hydrozoön* exhibits but a single tube, formed by the walls of the combined digestive and somatic cavity.

Histologically, the tissues of the *Actinozoa* are essentially the same as those of the *Hydrozoa*, consisting of the two fundamental layers, the 'ectoderm' and the 'endoderm.' In the *Actinozoa*, however, there is a much greater tendency to a differentiation of these into specialised structures, and in some members of the class muscular fibres are well developed. The ectoderm, especially, shows a tendency to break up into two layers, which are differentiated in opposite directions from an intermediate zone, and are termed by Huxley the 'ecderon' and 'enderon,' corresponding respectively to the epidermis and derma of man. Cilia are often present, especially in the interior of the somatic cavity, where they serve to promote a circulation of the digestive fluids contained therein. The sole digestive apparatus in the *Actinozoa* consists of a tubular stomach-sac, which communicates freely with the outer world by means of the mouth, and opens inferiorly directly into the general body-cavity. In most, the 'perivisceral space' between the body-walls and the digestive sac is subdivided into compartments by a series of vertical lamellæ, which are called the 'mesenteries' (*fig.* 25 *b*). Upon the faces of these

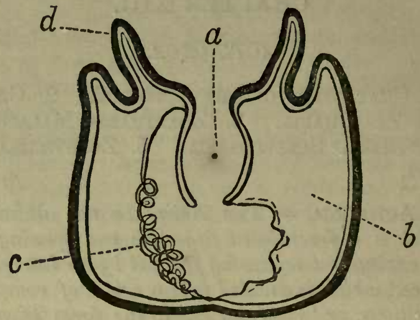


Fig. 25.—Morphology of Actinozoa. Diagrammatic vertical section of *Actinia*. *a*. Stomach-sac. *b*. Mesentery. *c*. Craspedum. *d*. Tentacle.

are borne the reproductive organs in the form of band-like ovaria or spermaria.

Thread-cells, often of very complicated structure, are almost universally present, some of the *Ctenophora* being apparently without them, and some of the *Actinozoa* are able to sting very severely.

A nervous system has not yet been proved to exist in any of the Actinozoa, except in the *Ctenophora*, and in none are there any traces of a vascular system.

Distinct reproductive organs occur in all the *Actinozoa*, but these are internal, and are never in the form of external processes as in the *Hydrozoa*. Sexual reproduction occurs in all the members of the class, but in many forms gemmation or fission constitutes an equally common mode of increase. Some *Actinozoa*, therefore, such as the common sea-anemones, are simple organisms, whilst others, such as the reef-building corals, are composite, the act of gemmation or fission giving rise to colonies composed of numerous zoöids united by a cœnosarc. In these cases the separate zoöids are termed 'polypes,' the term 'polypite' being restricted to the *Hydrozoa*. In the simple *Actinozoa*, however, the term 'polype' is employed to designate the entire organism. In other words, the 'actinosoma,' or entire body of any *Actinozoön*, may be composed of a single 'polype,' or of several such, produced by a process of continuous gemmation or fission and united by a common connecting structure, or cœnosarc.

Most of the *Actinozoa* are permanently fixed; some, like the Sea-anemones, possess a small amount of locomotive power; and one order, the *Ctenophora*, is composed of highly active, free-swimming organisms. Some of the *Actinozoa* are unprovided with any hard structure or support, as in the Sea-anemones and in all the *Ctenophora*; but a large number secrete a calcareous or horny framework, or skeleton, which is termed the 'coral,' or 'corallum.' In one family the corallum appears to be siliceous.

The *Actinozoa* are divided into four orders, viz.:—the *Zoantharia*, the *Alcyonaria*, the *Rugosa*, and the *Ctenophora*; but the last is sometimes placed amongst the *Hydrozoa*, and it has been recently proposed to remove the *Rugosa* also to the same class.

ORDER I. ZOANTHARIA.—The *Zoantharia* are defined *by the disposition of their soft parts in multiples of five or six, and by the possession of simple, usually numerous, tentacles. There may be no corallum, or rarely a 'sclerobasic' one. Usually there is a 'sclerodermic' corallum, in which the septa in each corallite, like the mesenteries, are arranged in multiples of five or six.*

The *Zoantharia* are divided into three sub-orders, the *Zoantharia Malacodermata*, the *Z. sclerobasica*, and the *Z. sclerodermata*; according as the corallum is entirely absent or very rudimentary, is 'sclerobasic,' or is 'sclerodermic.'

SUB-ORDER I. ZOANTHARIA MALACODERMATA.—In this section of the *Zoantharia* there is either no corallum or a very rudimentary one, in the form of a few scattered spicules. The 'actinosoma' is usually composed of but a single polype. (The term 'actinosoma' is a very convenient one to express in the *Actinozoa*, what 'hydrosoma' expresses in the *Hydrozoa*, namely, the entire organism, whether simple or compound.)

There are three families in this section, of which the *Actinidæ* will require a somewhat detailed examination, since they may be taken as typical of the entire class of the *Actinozoa*.

FAMILY 1. ACTINIDÆ.—The members of this family are commonly known as sea-anemones, and are distinguished by having no evident corallum, by being rarely compound, and by having the power of locomotion.

The body of a sea-anemone (*fig.* 26) is a truncated cone, or a short cylinder, termed the 'column,' and is of a soft, leathery consistence. The two extremities of the column are termed respectively the 'base' and the 'disc,' the former constituting the sucker, whereby the animal attaches itself at will, whilst the mouth is situated in the centre of the latter. Between the mouth and the circumference of the disc is a flat space, without appendages of any kind, termed the 'peristomial space.' Round the circumference of the disc are placed numerous tentacles, usually retractile, arranged in alternating rows, and amounting to as many as 200 in number in the common *Actinia.* The tentacles are tubular prolongations of the ectoderm and endoderm, containing diverticula from the

Fig. 26.—Actinidæ, *Tealia crassicornis,* the Dahlia Wartlet.

somatic chambers, and sometimes having apertures at their free extremities. The mouth leads directly into the stomach, which is a wide membranous tube, opening by a large aperture into the general body-cavity below, and extending about half way between the mouth and the base. The wide space between the stomach and column-wall is subdivided into a number of compartments by radiating vertical lamellæ, termed the 'primary mesenteries,' arising on the one hand from the inner surface of the body-wall, and attached on the other to the external surface of the stomach. As the stomach is considerably shorter than the column, it follows that the inner edges of the primary mesenteries below the stomach are free; and these free edges, curving at first outwards and then downwards and inwards, are ultimately attached to the centre of the base. Besides the primary mesenteries, there are other lamellæ which also arise from the body-wall, but which do not reach so far as the outer surface of the stomach, and are called 'secondary' and 'tertiary' mesenteries, according to their breadth. The reproductive organs are in the form of reddish bands, which contain ova and spermatozoa, and are situated on the faces of the mesenteries. Most of the *Actiniæ* are diœcious, that is to say, the same individual does not develop both ova and spermatozoa. Along the free margins of the mesenteries there also occur certain singular, convoluted cords, charged with thread-cells, and termed 'craspeda,' the function of which is not yet understood. It is believed, however, that the apertures, termed 'cinclides,' in the column-walls of some of the *Actinidæ* are for the emission of the craspeda. No traces of a nervous system have as yet been been proved to exist in any *Actinia*.

The embryo of the *Actinia* is a free-swimming ciliated body, at first rounded, but afterwards somewhat ovate. The rudimentary mouth is soon marked out by a depression at the larger extremity; thread-cells appear as a layer in the ectoderm; a fold is prolonged inwards from the mouth to form the digestive sac; and the primitive tentacles are at first either five or six in number, but usually double themselves rapidly.

FAMILY 2. ILYANTHIDÆ.—In this family there is no corallum, and the polypes are single and free, with a rounded or tapering base. *Ilyanthus* is in all essential respects identical with the ordinary *Actiniæ*, but it is of a pointed or conical shape, the base being much attenuated, though whether its habit of life is free, or not, is a matter of some uncertainty.

FAMILY 3. ZOANTHIDÆ.—In the *Zoanthidæ* there is a spicular corallum, and the polypes are attached by a fleshy or coriaceous base or cœnosarc. In *Zoanthus* the separate polypes closely resemble small *Actiniæ*, but they are united together at their bases by a thin fleshy cœnosarc.

SUB-ORDER II. ZOANTHARIA SCLEROBASICA.—The members of this sub-order are always composite; and always possess a corallum, but this is 'sclerobasic,' and there are no spicular tissue-secretions.

It appears advisable to explain here what is understood by the terms 'sclerobasic' and 'sclerodermic,' as applied to corals. The 'corallum' is the term which is applied to the hard structures deposited by the tissues of any *Actinozoön*, many of which are so familiarly known as 'corals.' Usually the corallum is composed of carbonate of lime; but it may be corneous, or partly corneous and partly calcareous; whilst in one family it appears to be siliceous. Whatever their composition may be, all coralla may be divided into two sections, termed respectively 'sclerobasic' and 'sclerodermic,' which must be carefully distinguished from one another. The 'sclerobasic' corallum, of which the red coral of commerce may be taken as the type, is in reality an exoskeleton, somewhat analogous to the shell of a *Crustacean*, being a true tegumentary secretion. At the same time, it is not a *shell* or external envelope, but it forms an axis, upon which the entire actinosoma is spread. The actinosoma, in fact, is inverted, and the 'sclerobasis' is secreted by the *outer* surface of the ectoderm. The sclerobasic corallum is, therefore, truly 'outside the bases of the polypes and their connecting cœnosarc, which, at the same time, receive support from the hard axis which they serve to conceal.'—(Greene.) Upon this view the sclerobasis is termed 'foot-secretion' by Mr. Dana.

The 'sclerodermic' corallum, on the other hand, is secreted *within* the bodies of the polypes, apparently by the *inner* layer of the ectoderm,—the 'enderon' of Huxley—and it is, therefore, termed 'tissue-secretion' by Mr. Dana. A sclerodermic corallum, of course, like the animal which produces it, may be simple or composite, according as it is produced by a single polype or by several united by a cœnosarc. It consists, therefore, of a single calcareous cup, or 'corallite;' or of several such united by a common calcareous bond or basis, the 'cœnenchyma.' Taking a single 'corallite' (*fig.* 27 *d*) as the

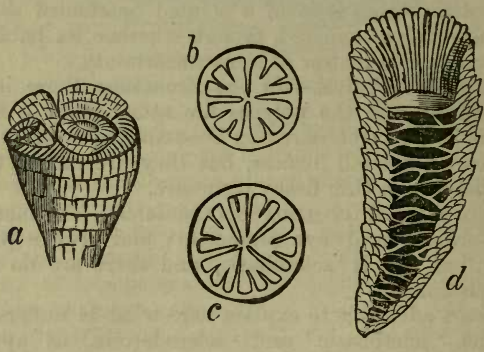


Fig. 27.—Morphology of Corals. *a.* Cup of *Acervularia ananas*, showing calicular gemmation, enlarged. *b.* Diagram of Rugose Coral (*Polycœlia profunda*), showing the quadripartite arrangement of the septa. *c.* Diagram of a recent coral, showing the sextuple arrangement of the septa. *d.* Vertical section of *Campophyllum flexuosum*, showing tabulæ.

type, we find that it shows its origin and nature plainly in its form. It consists of a cylindrical or conical tube of carbonate of lime, the outer wall of which is called the 'theca.' The upper part of the space included by the 'theca' is vacant, and it is termed the cup or 'calice'; but the lower part is subdivided into a series of chambers, or 'loculi,' by a series of radiating, vertical, calcareous plates, which are called the 'septa' (*fig.* 27, *b*). The septa extend from the inner surface of the theca towards its centre, where they usually unite to form an axial column, called the 'columella.' Many of the septa, however, do not reach the centre, but stop short at some distance from the columella, often being broken up into upright pillars, called 'pali.' The parts thus described as essentially composing a corallite in a typical sclerodermic corallum are related in the most obvious manner to the soft structures of the animal by which they are secreted. Thus, the 'theca' clearly corresponds to the 'column-wall,' or the general wall of the body; the 'columella,' when present, corresponds to 'that part of the enderon which forms the floor of the somatic cavity below the digestive sac,' whilst the 'septa' correspond to the 'mesenteries,' and, like them, are called 'primary' and 'secondary,' according as they reach the columella or fall short of it. When there are several corallites the bond of union between them, the 'cœnenchyma,' is secreted by the 'cœnosarc,' to which it corresponds. In many *Actinozoa*, however, the sclerodermic corallum is not present in the typical form above described, but simply in the form of calcareous spicules or nodules scattered through the tissues of the animal. There are, also, members of the class in which both a sclerodermic and a sclerobasic corallum are present, the latter constituting the main skeleton, whilst the former is represented by scattered spicules. The coral tissue itself is known as 'sclerenchyma,' and it varies considerably in texture, being sometimes extremely compact, and at other times very loosely put together.

From what has been said it will be seen that a sclerobasic corallum can easily be distinguished from a sclerodermic by inspection; the former being usually more or less smooth, and being invariably devoid of the cups or receptacles for the separate polypes, which are always present in the latter. The more important variations of detail which occur in both classes of corals will be noticed under the different families in which they occur.

Returning now to the *Zoantharia Sclerobasica*, we find the sub-order to contain the two families of the *Antipathidæ* and the *Hyalonemadæ* (or *Hyalochætidæ*). Of these the *Antipathidæ* are chiefly noticeable because of their likeness to some of the *Gorgonidæ*, from which, however, they are readily distinguished by the fact that the number of their tentacles is a multiple of six, whereas in the latter it is a multiple of four. *Antipathes* itself possesses a horny sclerobasic corallum, which may be simple or branched, and is covered with numerous small polypes, united together by a cœnosarc, and possessing six tentacles each.

The second family, that of the *Hyalonemadæ*, contains the so-called 'Glass-zoophytes,' the true nature and position of which has been a subject of much controversy. By Dr. Gray the *Hyalonemadæ* are believed to be true *Actinozoa*, and he defines them as follows:—'Social Zoanthoid polypes secreting a central, siliceous, internal, axial coil for their support. The upper half of the coil covered by a uniform cylindrical bark, regularly studded with retractile polypes.' The lower portion of the siliceous rope-like axis, which looks exactly like a skein of threads of glass, is sunk in the sand at the bottom of the sea. The upper portion of the *Hyalonema* is often occupied by a cup-shaped sponge, called *Carteria*, which Dr. Gray believes to be a parasitic growth. By Professors Löven, Perceval Wright, Wyville Thomson, and others the sponge *Carteria* is looked upon as the true artificer of the siliceous rope, and the polypes are regarded as parasitic, and as referable to *Palythoa*.

SUB-ORDER III. ZOANTHARIA SCLERODERMATA.—The members of this sub-order include the great bulk of the coral-producing or 'coralligenous' zoophytes of recent seas. They are defined by the possession of a sclerodermic corallum, the parts of which are arranged in multiples of five or six. The actinosoma may be simple, consisting of a single polype, or it may be composite, consisting of several polypes united by a cœnosarc.

The divisions of the sub-order are founded upon the nature of the corallum, for the due comprehension of which it will be necessary to consider some points in connection with these structures somewhat more minutely. As already described, a typical corallite consists of an outer wall, or 'theca,' with a cup or 'calice' above, and divided below into numerous chambers or 'loculi,' by vertical partitions or 'septa.' Often the larger, or 'primary,' septa coalesce centrally to form a median calcareous rod, or 'columella.' The chief additional structures to be remarked are what are known as 'tabulæ,' and 'dissepiments.' The 'tabulæ' (*fig.* 27, *d*) are transverse plates or floors running at right angles to the axis of the corallite, and dividing the theca into so many horizontal compartments or stories, each of which is vertically subdivided by the septa, when these exist. As a rule, however, the septa are absent when there are tabulæ, though the two structures coexist in many extinct corals. The 'dissepiments' are incomplete transverse plates which, 'growing from the sides of the septa, interfere, to a greater or less extent, with the perfect continuity of the loculi.'—(Greene.) The septa, too, are often furnished with styliform or spine-like processes growing from their sides, which often meet so as to form 'transverse props extending across the loculi like the bars of a grate, and termed "synapticulæ."'

The *Zoantharia Sclerodermata* are divided into the four following groups, founded upon the characters of the corallum:—

1. *Tabulata.* — Septa rudimentary, or entirely absent; tabulæ well-developed and dividing the visceral chamber into a series of stories.

2. *Perforata.*—Septa well developed; dissepiments rudimentary; no tabulæ. Corallum composed of porous sclerenchyma.

3. *Aporosa.*—Septa well developed, lamellar; no tabulæ. Corallum composed of compact, imperforate sclerenchyma.

4. *Tubulosa.*—Septa indicated by mere striæ; thecæ pyriform, occasionally united by a basal cœnenchyma.

Gemmation and Fission amongst Corals.—As regards the modes in which the composite corals are produced the following is a summary of Professor Greene's remarks upon this subject. (See *Cœlenterata*, p. 185 *et seq.*) The production of the composite *Actinozoa* is effected either by gemmation or by fission. In the former method three varieties have been distinguished, termed respectively 'basal,' 'parietal,' and 'calicular' gemmation.

In basal gemmation the mode of increase is by means of a rudimentary cœnosarc, which is put forth by the original polype, and from which the young polype-buds are produced. It 'affords very different products according as the cœnosarc remains soft, or deposits a cœnenchyma; appears under the form of stolons, or of stouter connecting stems; or even spreads out in several directions as a continuous horizontal expansion;' in which last case the youngest polypes are, of of course, those nearest to the periphery of the mass.

The parietal mode of gemmation is the commonest, and it gives rise chiefly to dendroid, or tree-like, corals. In this method the buds are produced from the sides of the original polype, and they often repeat the process indefinitely.

Calicular gemmation is not known to occur in any recent coral, but it was a common mode of increase amongst extinct forms. In this method 'the primitive polype sends up from its oral disc two or more similar buds; these, in their turn, produce other young polypes, and thus the process is repeated until an inverted pyramidal mass of considerable size is produced, all the parts of which rest upon the narrow base of the first budding polype' (*fig.* 27, *a*). Fission in the *Actinozoa* differs from gemmation chiefly in the fact, that the polypes produced fissiparously resemble one another in organisation, and often in size, as soon as they become distinct. In gemmation, on the other hand, the polype-bud consists primarily of a mere process of ectoderm and endoderm, enclosing a cæcal process of the somatic cavity, and a mouth and other structures are at first wanting. Amongst the coralligenous *Actinozoa* fission is usually effected by 'oral cleavage,' the divisional groove commencing at the oral disc, and deepening to a certain extent, the proximal extremity always remaining undivided. More rarely fission 'is effected by the separation of small portions from the attached base of the primitive organism, whose form and structure they subsequently, by gradual development, tend to assume.'

'The coral-structures which result from a repetition of the fissiparous process are of two principal kinds, according as they tend most to increase in a *vertical* or in a *horizontal* direction. In the first of these cases the corallum is *cæspitose*, or tufted, convex on its distal aspect, and resolvable into a succession of short diverging pairs of branches, each resulting from the division of a single corallite.' In the second case the coral becomes *lamellar*. 'Here the secondary corallites are united throughout their whole height, and disposed in a linear series, the entire mass presenting one continuous theca.' Both these forms of corallum 'are liable to become *massive* by the union of several rows or tufts of corallites throughout the whole or a portion of their height. An illustration of this is afforded by the large *gyrate* corallum of *Meandrina*, over the surface of whose spheroidal mass the calicine region of the combined corallites winds in so complex a manner as at once to suggest that resemblance to the convolutions of the brain, which its popular name of Brain-stone Coral has been devised to indicate.'

CHAPTER XIV.

ALCYONARIA.

ORDER II. ALCYONARIA.—The second great division of living *Actinozoa* is that of the *Alcyonaria*, defined by the possession of *polypes with eight pinnately-fringed tentacles, the mesenteries and somatic chambers being also some multiple of four. The corallum, when present, is usually sclerobasic, or spicular; if 'thecæ' are present, as is rarely the case, there are no septa.*

The *Alcyonaria* differ numerically from the *Zoantharia* in having their soft parts arranged in multiples of *four*, instead of *five* or *six*, as in the latter. Their tentacles, too, are pinnate, and are not simply rounded. Numerically the *Alcyonaria* agree with the extinct order *Rugosa*, but the latter invariably possess a well developed sclerodermic corallum, the thecæ of which exhibit either septa or tabulæ, or both combined.

With the exception of the single genus *Haimeia*, the *Alcyonaria* are all composite, their polypes being connected together by a common cœnosarc, 'through which permeate prolongations of the somatic cavity of each, forming a sort of canal-system, whose several parts freely communicate,' and permit of a free circulation of nutrient fluids. Anatomically the polypes of the *Alcyonaria* do not differ in any essential particular from those of the *Zoantharia*; the numerical distinction being the one by which they are chiefly separated from one another. The *Alcyonaria* are divided into four families, viz. the *Alcyonidæ*, the *Tubiporidæ*, the *Pennatulidæ*, and the *Gorgonidæ*.

Family I. Alcyonidæ.—This family is characterised by the possession of a fixed actinosoma, which is provided with a sclerodermic corallum in the form of calcareous spicula imbedded in the tissues.

Alcyonium may be taken as the type of the family, and it is well known to fishermen under the name of 'Dead-men's fingers.' It forms spongy-looking, orange-coloured crusts or lobate masses, which are attached to submarine objects, and are covered with little stellate apertures, through which the delicate polypes can be protruded and retracted at will. The polypes communicate with one another by an anastomosing system of aquiferous tubes, and the corallum is in the form of cruciform, calcareous spicula scattered through its substance.

Family II. Tubiporidæ.—In the *Tubiporidæ*, or 'organ-pipe corals,' of which *T. musica* is a familiar example, there is a well developed sclerodermic corallum, with thecæ, but without septa. The corallum is composed of a number of bright red, tubular, cylindrical thecæ, which are united together externally by horizontal plates or floors, which are termed 'epithecæ,' and represent external tabulæ. The polypes are usually bright green in colour, and possess eight tentacles each.

Family III. Pennatulidæ.—The *Pennatulidæ*, or 'Sea-pens,' are defined by their free habit, and by the possession of a sclerobasic, rod-like corallum, sometimes associated with sclerodermic spicules.

Pennatula, or the 'Cock's-comb,' consists of a free cœnosarc, the upper end of which is fringed on both sides with feather-like lateral pinnæ, which bear the polypes; whilst its proximal end is smooth and fleshy, and is probably sunk in the mud of the sea-bottom. This latter portion of the cœnosarc is, likewise, strengthened by a long, slender, styliform sclerobasis, resembling a rod in shape, whilst spicula occur also in the tentacles and ectoderm. Some *Pennatulæ* are phosphorescent.

Fig. 28.—Pennatulidæ. *Virgularia mirabilis.* *a.* A portion of the stem in the living condition, enlarged. *b.* Portion of the stem in its dead condition.

In *Virgularia* (*fig.* 28), which, like *Pennatula*, occurs not uncommonly in British seas, the actinosoma is much longer and more slender than in the preceding, and the polype-bearing fringes are short. The polypes have eight tentacles. The sclerobasis is in the form of a long calcareous rod, like a knitting-needle, and part of it is usually naked. No spicula are found in the tissues of *Virgularia*.

FAMILY IV. GORGONIDÆ.—In the *Gorgonidæ*, or 'Sea-shrubs,' there is an arborescent cœnosarc permanently rooted and provided with a grooved, or sulcate, branched sclerobasis, which is sometimes associated with true tissue-secretions, termed 'dermo-sclerites.'

The sclerobasis of the *Gorgonidæ* varies a good deal in its composition. In some it is corneous, and these have often been confounded with the *Antipathidæ*, amongst the *Zoantharia*. The distinction, however, between them is easy, when it is remembered that the polypes in the *Gorgonidæ* have tentacles in multiples of *four*, whilst in the *Antipathidæ* they are in *sixes*. The sclerobasis, too, in the former is always marked by grooves, whereas in the latter it is always either smooth or spinulous. In *Isis* and *Mopsea* the sclerobasis consists of alternate calcareous and horny segments, branches being developed in the former from the calcareous, and in the latter from the horny segments.

In *Corallium rubrum*, the 'red coral' of commerce, the sclerobasis is unarticulate, or unjointed, and is entirely calcareous. It is the most familiar member of the family, and is largely imported for ornamental purposes. Red coral consists of a branched densely calcareous sclerobasis, which is finely grooved upon its surface, and is of a bright red colour. The corallum is invested by a cœnosarc, also of a red colour, which is studded by the apertures for the polypes, which are white, and possess eight pinnately-fringed tentacles. The entire cœnosarc is channelled out by a number of anastomosing canals, which communicate with the somatic cavities of the polypes, and are said to be in direct communication with the external medium by means of numerous perforations in their walls. The entire canal system is filled with a nutrient fluid, containing corpuscles, and known as the 'milk.'

CHAPTER XV.

RUGOSA.

ORDER III. RUGOSA.—The members of this order are entirely extinct, and, with the single exception of *Holocystis elegans* from the Lower Cretaceous Rocks, are not known to occur in deposits younger than the Palæozoic epoch. With the soft parts of the *Rugosa* we are, of course, entirely unacquainted, and the definition of the order must, therefore, be founded upon the characters of the corallum. The corallum in the *Rugosa* is highly developed, sclerodermic, with true thecæ, and often presenting both septa and tabulæ combined. The septa are in multiples of *four* (*fig.* 27 *b*), unlike the recent sclerodermic coralla, in which they are in multiples of *five* or *six*. There is, further, no true cœnenchyma. Some of the Rugosa are simple; but others are composite, increasing either by parietal or by calicular gemmation. According to Professor Agassiz the *Rugosa* and the *Tabulate* division of the *Zoantharia* ought not to be considered as belonging to the *Actinozoa*, but should be placed amongst the *Hydrozoa*. This radical change, however, cannot be accepted without the production of very conclusive evidence in its favour.

DISTINCTIONS BETWEEN THE CORALLA OF THE ORDERS OF ACTINOZOA.—Having now considered all the orders of the Actinozoa in which coralla are developed, it may be as well briefly to review their more striking differences.

In the first place a sclerobasic corallum may be distinguished by inspection from a sclerodermic corallum by the fact that the latter, unless composed simply of spicules, presents the cups or 'thecæ,' in which the polypes were contained; the surface of the former being invariably destitute of these receptacles.

A sclerobasic corallum is found in the families *Antipathidæ* and *Hyalonemadæ* amongst the *Zoantharia*, and in the families *Pennatulidæ* and *Gorgonidæ* amongst the *Alcyonaria*; the following being the differences between them :—

1. *Antipathidæ.*—Sclerobasis spinulous or smooth; tentacles and soft parts in multiples of six.

2. *Hyalonemadæ.*—Sclerobasis siliceous, composed of numerous threads; tentacles in multiples of five.

3. *Pennatulidæ.*—Sclerobasis sulcate, free; soft parts in multiples of four.

4. *Gorgonidæ.*—Sclerobasis sulcate, attached proximally: soft parts in multiples of four.

Sclerodermic coralla fall under two heads, according as they are simply composed of scattered spicules, or are provided with true *thecæ.*

I. *Spicular* coralla occur in the *Zoantharia Malacodermata* (occasionally), and in the *Alcyonidæ*; and no differences can be stated between the coralla themselves. The animals, however, differ entirely, the soft parts of the former being in multiples of five or six, those of the latter being in multiples of four.

II. A *thecal*, sclerodermic corallum occurs in three distinct sections of *Actinozoa*:—1. In the *Zoantharia Sclerodermata.* 2. In the *Tubiporidæ*, amongst the *Alcyonaria*; and 3. In the *Rugosa*; and the following are the distinctions between them:—

1. *Zoantharia Sclerodermata.*—Septa in multiples of five or six, sometimes absent; tabulæ often present.

2. *Tubiporidæ.*—Septa absent; thecæ united externally by distinct, horizontal 'epithecæ.'

3. *Rugosa.*—Septa in multiples of four; tabulæ usually present.

CHAPTER XVI.

CTENOPHORA.

Order IV. Ctenophora.—The *Ctenophora* comprise '*transparent, oceanic, gelatinous Actinozoa, swimming by means of "ctenophores," or parallel rows of cilia disposed in comb-like plates. No corallum.*'—(Greene.)

The members of this order are all free-swimming organisms, and they are placed by many amongst the *Hydrozoa*, from which, however, they appear to be clearly separated by the possession of a differentiated digestive sac, as well as by their analogies with the *Actinozoa*, and their generally superior degree of organisation.

Pleurobrachia (*Cydippe*) (*fig.* 29) may be taken as the type of the order, the structure of all being similar to this in essential points. *Pleurobrachia* possesses a transparent, colourless,

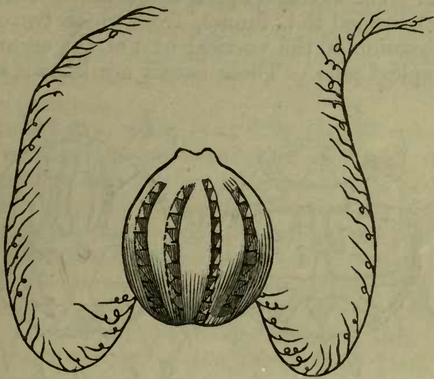


Fig. 29.—Ctenophora. *Pleurobrachia pileus.*

gelatinous, melon-shaped body, or 'actinosoma,' in which the two poles of the sphere are termed respectively the 'oral' and 'apical,' and the rest of the body constitutes the 'interpolar region.' At the oral pole is the transverse mouth, bounded by lateral, slightly protuberant margins. 'Eight meridional bands, or "ctenophores" bearing the comb-like fringes, or characteristic organs of locomotion, traverse at definite intervals the interpolar region, which they divide into an equal number of lune-like lobes, termed the "actinomeres;" but this division of the body does not extend into the immediate vicinity of the poles, before reaching which the ctenophores gradually diminish in diameter, each terminating in a point.'—(Greene.) The normal number of the ctenophores appears to be eight, and each consists of a band of surface elevated transversely into a number of ridges, to each of which a fringe of cilia is attached, so as to form a comb-like plate. The cilia in the middle of these transverse ridges are the longest, and they gradually diminish in length towards the sides, so that the form of each comb is somewhat crescentic. Besides the comb-like groups of vibratile cilia, *Pleurobrachia* is provided with two very long and flexible tentacular processes, which are fringed on one side with smaller cirrhi. These filamentous processes arise each from a sac, situated on one of the lateral actinomeres, within which they can be completely and instantaneously retracted at the will of the animal.

The mouth of *Pleurobrachia* (*fig.* 30, *a*) opens into a fusiform digestive sac, or stomach (*b*), the lower part of which is provided with brown cells, supposed to discharge the functions of a liver. The stomach opens below into a shorter and wider cavity (*c*), termed the 'funnel,' from which two canals diverge in the direction of the vertical axis of the organism, to open at the 'apical pole.' These canals are known as the 'apical

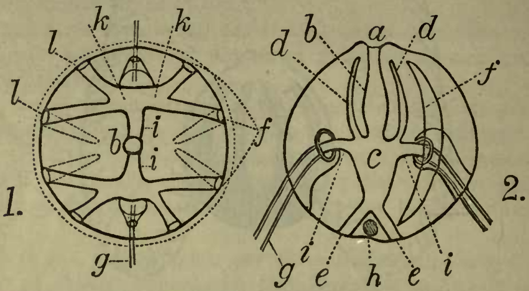


Fig. 30.—Morphology of Ctenophora. 1. Diagrammatic transverse section of *Pleurobrachia*. *b*. Digestive cavity; *i i*. Primary radial canals; *k k*. Secondary radial canals; *l l*. Tertiary radial canals; *g*. Tentacle. 2. Longitudinal section of *Pleurobrachia*. *a*. Mouth; *b*. Digestive cavity. *c*. Funnel; *d d*. Paragastric canals; *e e*. Apical canals; *f*. Ctenophoral canal; *g*. Tentacle; *h*. Ctenocyst. (After Greene.)

canals' (*e*), and their apertures as the 'apical pores.' From the funnel two other pairs of canals are given off. Of these, one pair—known as the 'paragastric canals'—turns upwards, one running parallel to the digestive sac on each side (*d*), and 'terminating cæcally before quite reaching the oral extremity.' The second pair of canals (*i*)—the so-called 'radial canals'—branch off from the funnel laterally, each dividing into two, and then again into two, as they proceed towards the periphery of the body. Thus, the two 'primary' radial canals produce four 'secondary' canals (*k*), and these, in turn, give rise to eight 'tertiary' radial canals (*l*), which finally terminate by opening 'at right angles into an equal number of longitudinal vessels, the "ctenophoral canals" (*f*), whose course coincides with that of the eight locomotive bands. These canals end cæcally both at their oral and apical extremities.'—(Greene.) The whole of this complex canal-system is lined by a ciliated endoderm, and a constant circulation of the included nutrient fluids is thus maintained.

Immediately within the apical pole is situated a small cyst or vesicle, supposed to be an organ of sense, and termed the 'ctenocyst' (*h*). In structure the 'ctenocyst' consists of a spherical vesicle, lined with a ciliated epithelium, and filled with a clear fluid, which contains mineral particles, probably of carbonate of lime. Resting upon the ctenocyst is a small ganglionic mass, giving origin to a number of delicate filaments, and generally admitted to be a rudimentary form of nervous system. The reproductive organs of *Pleurobrachia* are in the form of folds, containing either ova or spermatozoa, and situated beneath the endodermal lining of the ctenophoral canals, one on each side.

The embryo *Pleurobrachia* is at first rudely cylindrical in form, a belt of cilia passing round the middle of its body. This soon breaks up into two lateral groups, which eventually disappear altogether, 'the ctenophores, at first very broad and few in number, at an early period taking on the performance of their special function.'—(Greene.)

As regards the homologies between *Actinia* and *Pleurobrachia*, the following may be quoted from Professor Greene:—

'If now a comparison be made between this nutrient system' (the canal-system of the *Ctenophora*) 'and that of Actinia, the digestive sacs of the two organisms are clearly seen to correspond in form, in relative size, and mode of communication with the somatic cavity. The funnel and apical canals of *Pleurobrachia*, though more distinctly marked out, are the homologues of those parts of the general cavity, which in *Actinia* are central in position, and underlie the free end of the digestive sac. So also the paragastric and radial canals may be likened to those lateral portions of the somatic cavity of *Actinia*, which are not included between the mesenteries. Lastly, the ctenophoral canals of Pleurobrachia and the somatic chambers of *Actinia* appear to be truly homologous, the chief difference between the two forms being that while in the latter the body-chambers are wide and separated by very thin partitions, they are in *Pleurobrachia* reduced to the condition of tubes: the mesenteries which intervene becoming very thick and gelatinous, so as to constitute, indeed, the principal bulk of the body.'

The remaining members of the *Ctenophora* conform in most essential respects with *Pleurobrachia*, the most important difference being found in the canal-system. For purposes of comparison this system may be divided into four portions as follows:—1. The 'axial system,' consisting of the mouth, stomach, funnel, and apical canals. 2. The 'paraxial system,' comprising the paragastric canals. 3. The 'radial system,' comprising the primary, secondary, and tertiary radial canals. 4. The 'ctenophoral system,' consisting of the tubes which run underneath the locomotive bands.

In *Beroe*, which is in other respects very similar to *Pleuro-*

brachia, the axial system of canals is the same as we have seen in the latter. The paraxial system, however, consists of *two* pairs of paragastric canals, which, instead of terminating cæcally, open into a circular canal which surrounds the mouth. The ctenophoral canals, likewise, open into the oral vessel, instead of terminating cæcally as in *Pleurobrachia*. Lastly, the radial system is not developed, the ctenophoral canals simply curving round towards their apical extremities, and opening into the funnel directly.

Amongst the *Beroidæ* the mouth extends entirely across the oral extremity of the body; hence they have been termed *Eurystomata*, the term *Stenostomata* being applied collectively to all the other *Ctenophora*.

The *Beroidæ* further differ from *Pleurobrachia* in being destitute of the long tentacular appendages, so characteristic of the latter.

In *Cestum*, or 'Venus' Girdle,' 'elongation takes place to an extraordinary extent, at right angles to the direction of the digestive track, a flat, ribbon-shaped body, three or four feet in length, being the result.'

DIVISIONS OF THE CTENOPHORA.—The following arrangement of the *Ctenophora* has been adopted by Gegenbaur (see Greene):—

Order CTENOPHORA.

Sub-order I. *Stenostomata*.

Family I. CALLYMMIDÆ.
Body furnished with a pair of antero-posterior oral lobes, and other smaller lateral apendages. *Tentacles* various, turned towards the mouth.

Family II. CESTIDÆ.
Body ribbon-shaped, extended in a lateral direction, without oral lobes. *Tentacles* two in number, antero-posterior, turned towards the mouth.

Family III. CALLIANIRIDÆ.
Body produced into a pair of wing-like lateral lobes, bearing the ctenophores. *Tentacles* two in number, lateral, turned from the mouth.

Family IV. PLEUROBRACHIADÆ.
Body oval or spheroidal, without oral lobes. *Tentacles* two in number, lateral, turned from the mouth.

Sub-order II. *Eurystomata*.

Family V. BEROIDÆ.
Body oval, elongated, without oral lobes. *Tentacles* absent.

CHAPTER XVII.

DISTRIBUTION OF ACTINOZOA.

1. Distribution of Actinozoa in Space. 2. Coral Reefs. 3. Distribution of Actinozoa in Time. 4. Appendix.

Distribution of Actinozoa in Space.—The *Zoantharia malacodermata* appear to have an almost cosmopolitan range, sea-anemones being found on almost every coast; some of the tropical forms attaining a very large size. The *Ctenophora*, too, have an almost world-wide distribution, occurring in all seas from the equator to within the arctic circle. In habit all the *Ctenophora* are pelagic, being found, like the oceanic *Hydrozoa*, swimming near the surface far from land. *Pennatulidæ* and *Gorgonidæ* are found in the seas of the temperate zone, but the latter attain their maximum within the tropics. The Red Coral of commerce (*Corallium rubrum*) is derived from the Mediterranean.

The so-called 'reef-building' Corals have their distribution conditioned by the mean winter temperature of the sea, a temperature of not less than 66° being necessary for their existence. They are found chiefly on the east coast of Africa, the shores of Madagascar, the Red Sea and Persian Gulf, throughout the Indian Ocean and the whole of Polynesia, and around the West Indian Islands and the coast of Florida.

All known *Actinozoa* are marine, no member of the class having hitherto been found in fresh water.

Coral-reefs.—A 'coral-reef' is a mass of coral, sometimes many hundred miles in length, produced by the combined growth of different species of coralligenous *Actinozoa*. As before said, a mean winter temperature of not less than 66° is necessary for their existence, and, therefore, nothing worthy of the name of a 'coral-reef' is to be found in seas so far removed from the equator as to possess a lower winter temperature than the above. The head-quarters of the reef-building corals may be said to be around the islands and continents of the Pacific Ocean. According to Darwin, coral-reefs may be divided into three principal forms, viz. Fringing-reefs, Barrier-reefs, and Atolls, distinguished by the following characters:—

1. *Fringing-reefs* (*fig.* 31, 1).—These are reefs, seldom of great size, which may either surround islands, or skirt the

shores of continents. These shore-reefs have no channel of any great depth intervening between them and the land, and the soundings on their seaward margin indicate that they repose upon a gently sloping surface.

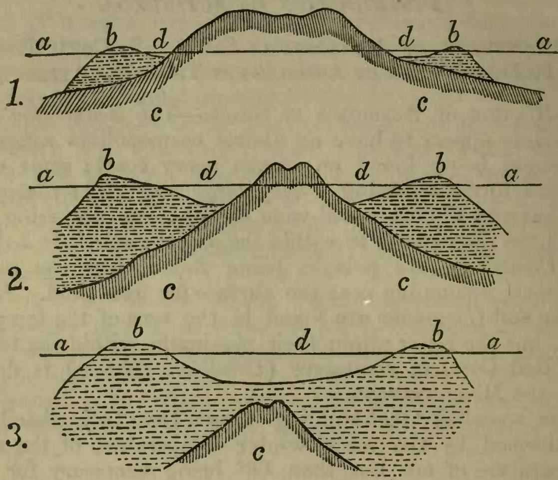


Fig. 31.—Structure of coral reefs. 1. Fringing-reef. 2. Barrier-reef. 3. Atoll. *a.* Sea level; *b.* Coral-reef; *c.* Primitive land; *d.* Portion of sea within the reef, forming a channel or lagoon.

2. *Barrier-reefs* (*fig.* 31, 2).—These, like the preceding, may either encircle islands, or may skirt continents. They are distinguished from fringing-reefs by the fact that they occur usually at a much greater distance from land, that there intervenes a channel of deep water between them and the shore, and that soundings taken close to their seaward margin indicate enormous depths. If the barrier-reef surround an island, it is sometimes called an 'encircling barrier-reef,' and it constitutes with its island what is called a 'lagoon-island.'

As an example of this class of reefs may be taken the great barrier-reef on the N.E. coast of Australia, the structure of which is on a perfectly colossal scale. This reef runs, with a few breaches in its continuity, for a distance of more than a thousand miles, its average distance from the shore being between twenty and thirty miles, and the depth of the inner channel being from ten to sixty fathoms, whilst the sea outside is 'profoundly deep' (in some places over 1,800 feet).

3. *Atolls* (*fig.* 31, 3).—These are nearly circular reefs of coral, enclosing a central expanse of water or lagoon. They

seldom form complete rings, the reef being usually breached by one or more openings. In their structure they are identical with 'encircling barrier-reefs,' and differ from these only in the fact that the lagoon which they enclose does not contain an island in its centre.

If a coral-reef be observed,—say a portion of an encircling barrier-reef—the following are the general phenomena which may be noticed. The general shape of the reef is triangular, presenting a steep and abrupt wall on the seaward side, and having a long and gentle slope towards the land. The outer margin of the reef is exposed to the beating of a tremendous surf, whilst the soundings taken just outside the line of breakers always indicate great depths. The longer inner slope is washed by the calm waters of the inner lagoon or channel. The reef is only very partially composed of living corals, which are found to occupy a mere strip, or zone, along the sea-ward margin of the reef, whilst all above this, as well as all below, is constituted by dead coral, or 'coral-rock.'

As to the method in which such a reef is produced, the following facts have been established:—

A. The coral-producing polypes cannot exist at levels higher than extreme low water, exposure to the sun even for a short period, proving rapidly fatal. It follows from this that no coral-reef can be raised above the level of the sea by the efforts of its builders. The agency whereby reefs are raised above the surface of the sea, is the denuding power of the breakers which constantly fall upon their outer margins. These detach large masses of dead coral, and heap them up in particular places, until an island is gradually produced. The fragments thus accumulated are compacted together by the finer *detritus* of the reef, and are cemented together by the percolation of water holding carbonate of lime in solution. In this way the upper surface of the reef, along a line of greater or less breadth, is more or less completely raised above the level of high water. It is obvious, however, that the reef might be entirely destroyed by a continuation of this process—the sea being quite competent to undo what it had done—unless some counteracting force were brought into play. This counteracting force is found in the vital activity of the living corals which form the seaward margin of the reef, and which, by their growth, prevent the sea from *always* destroying the masses of sediment which it may have thrown up.

B. The coral-producing polypes cannot exist at depths exceeding some 15 to 30 fathoms. It follows from this that no coral-reef can be commenced upon a sea-bottom deeper than about 30 fathoms. The question now arises; in what way have reefs been produced, which, as we have seen, rise out of depths of 300 fathoms or more? This question has been answered by Darwin, who showed that the production of barrier-reefs and atolls was really to be ascribed to a gradual subsidence of the foundations upon which they rest. Thus, if a fringing-reef which surrounds an island is supposed gradually to sink beneath the sea, the upward growth of the corals will neutralise the downward movement of the land, so far, at any rate, that the reef will appear to be stationary, whilst it is really growing upwards. The island, however, as subsidence goes on, will gradually diminish in size, and a channel will be formed between it and the reef. If the depression should be still continued, the island will be reduced to a mere peak in the centre of a lagoon; and the reef, from a 'fringing-reef,' will have become converted into an 'encircling barrier-reef.' As the growth of the reef is chiefly vertical, the continued depression will, of course, have produced deep water all round the reef. If the subsidence be continued still further, the central peak will disappear altogether, and the reef will become a more or less complete ring surrounding a central expanse of water; thus becoming converted into an 'atoll.' The production, therefore, of encircling barrier-reefs and atolls is thus seen to be due to a process of subsidence of the sea-bottom. The existence, however, of fringing-reefs is only possible when the land is either slowly rising, or is stationary, and as a matter of fact, fringing-reefs are often found to be conjoined with up-raised strata of post-tertiary age.

C. Different portions of a coral reef are occupied by different kinds of corals. According to Agassiz, the basement of a coral-reef is formed by a zone of massive *Astræans*. These cannot flourish at depths of less than six fathoms of water, and consequently when the surface of the reef has reached this level, the *Astræans* cease to grow. Their place is now taken by *Meandrinas* (Brain-corals) and *Porites*, but these, too, cannot extend above a certain level. Finally the summit of the reef is formed by an aggregation of less massive corals, such as *Madreporidæ*, *Milleporidæ*, and *Gorgonidæ*.

DISTRIBUTION OF ACTINOZOA IN TIME.—With the single exception of the Mollusca, no division of the animal kingdom contributes such important and numerous indications of its past existence, as the *Actinozoa*.

In the Palæozoic Rocks, the majority of corals belong to the division *Rugosa*, these seeming to have filled the place now taken by the sclerodermic *Zoantharia*. The order *Rugosa* is entirely Palæozoic, with the single exception of the genus *Holocystis*, which is represented in the Secondary Rocks by a single species (viz. *H. elegans*, from the Lower Greensand). In the lower Palæozoic Rocks the *Rugosa* are especially abundant; but in the Permian formation the order is represented by the single genus *Polycœlia*.

The *Zoantharia Sclerodermata*, though attaining their maximum at the present day, nevertheless are well represented in past time, beginning in the Silurian period. One subdivision of this group, the *Tubulosa*, is entirely confined to the Palæozoic Rocks, and another, the *Tabulata*, is chiefly Palæozoic. The *Perforata* and *Aporosa*, on the other hand, are more abundant in the Mesozoic and Kainozoic Epochs.

The *Zoantharia Sclerobasica* are hardly known as fossils, but the Miocene deposits of Piedmont (Middle Tertiary) have yielded a species of *Antipathes*.

The *Zoantharia Malacodermata*, from the soft nature of their bodies, are obviously incapable of leaving any traces of their existence; though we are by no means therefore justified in asserting that they did not exist in past geological epochs.

The *Alcyonaria* are very doubtfully represented in rocks older than the Chalk; the Lower Silurian fossil, called *Protovirgularia*, being more probably referable to the *Hydrozoa*. One of the *Pennatulidæ* (viz. *Graphularia*) has been found in the London Clay (Eocene), and the same formation has likewise yielded two species of *Gorgonidæ* (*Mopsea* and *Websteria*). The genus *Corallium* has likewise been found in deposits of Miocene age.

The *Ctenophora*, being entirely destitute of any hard structures, are not known at all as occurring in the fossil condition.

APPENDIX GIVING A TABULAR VIEW OF THE DIVISIONS OF THE ZOANTHARIA SCLERODERMATA AND RUGOSA (AFTER MILNE-EDWARDS AND JULES HAIME).

A. The *Zoantharia Sclerodermata* are defined by the possession of a sclerodermic corallum, the parts of which are arranged in multiples of five or six. Septa generally well developed, but not combined, as a rule, with tabulæ.

The following chief divisions of the *Zoantharia Sclerodermata* are, with few alterations, those adopted by the above mentioned authorities:—

I. TABULATA.—Septa rudimentary or absent; tabulæ well developed, dividing the visceral chamber into a series of stories.

1. *Thecidæ.*—Corallum massive; a dense spurious cœnenchyma formed by the lateral union of the septa; tabulæ numerous.
2. *Favositidæ.*—Septa and corallites distinct; little or no true cœnenchyma.
3. *Seriatoporidæ.*—Corallum arborescent; sclerenchyma abundant and compact; tabulæ few.
4. *Milleporidæ.*—Corallum massive or foliaceous; septa not numerous; sclerenchyma tabular or cellular.

II. Perforata.—Septa well developed; no tabulæ; dissepiments rudimentary; sclerenchyma porous.

5. *Eupsammidæ*.—Corallum simple or composite; septa well developed and lamellar; columella spongiose.

6. *Poritidæ*.—Corallum composed of spongy, reticulated sclerenchyma. Septa never lamellar, but consisting wholly of a more or less definite series of trabeculæ; no tabulæ.

7. *Madreporidæ*.—Corallum usually composite; cœnenchyma abundant and spongy; thecæ porous, not distinct from the cœnenchyma; septa distinct, but slightly perforate.

III. Aporosa.—Septa well developed, completely lamellar, and primitively consisting of six elements; no tabulæ; sclerenchyma imperforate.

8. *Fungidæ*.—Corallum simple or compound; thecæ ill developed, and somewhat porous; no dissepiments or tabulæ; synapticulæ numerous.

9. *Astræidæ*.—Corallum simple or compound; no proper cœnenchyma; numerous dissepiments; no synapticulæ. Corallites well defined and separated from one another by perfect walls.

10. *Oculinidæ*.—Corallum composite; cœnenchyma abundant and compact; dissepiments few in number. Walls of the corallites without perforations, not distinct from the cœnenchyma.

11. *Turbinolidæ*.—Corallum usually simple; no cœnenchyma; septa well developed; no dissepiments, nor synapticulæ.

IV. Tubulosa.—Septa indicated by mere striæ; thecæ pyriform; corallites sometimes connected by a creeping basal cœnenchyma.

12. *Auloporidæ*.—This being the only family in the *Tubulosa*, its characters are necessarily the same as those of the division itself.

B. Order Rugosa.—Characterised by the possession of a sclerodermic corallum, usually with septa and tabulæ combined, the former being in multiples of four. The corallites are always distinct, and are never united together by a cœnenchyma. The septa are usually incomplete, but are never porous, and never bear synapticulæ. The order is divided into the following four families:—

Family 1. *Stauridæ*.

Corallum simple or composite; septa incomplete, united by lamellar dissepiments; four large primary septa, forming a cross.

Family 2. *Cyathaxonidæ*.

Corallum simple; septa complete; no dissepiments or tabulæ; without four primary septa.

Family 3. *Cyathophyllidæ*.

Corallum simple or composite; septa incomplete; tabulæ generally present.

Family 4. *Cystiphyllidæ*.

Corallum simple, composed chiefly of a vesicular mass, with but slight traces of septa.

ANNULOIDA.

CHAPTER XVIII.

1. General Characters of the Annuloida. 2. General Characters of the Echinodermata.

Sub-kingdom III. Annuloida (= *Echinozoa*, Allman).—This sub-kingdom was proposed by Professor Huxley for the reception of the two groups of the *Echinodermata* and the *Scolecida*, of which the former belonged to the old sub-kingdom *Radiata*; whilst the latter was formerly classed with the *Annulosa*. The same sections have been grouped by Professor Allman together, under the name *Echinozoa*; the *Rotifera*, however, being excluded from this division and classed with the *Annulosa*. By others, again, the *Annuloida* are looked upon as a section of the *Annulosa*, and not as a distinct sub-kingdom. Provisionally, however, it seems best to regard the *Annuloida* as one of the primary divisions of the animal kingdom, it being impossible, in the meanwhile, to frame a definition common to it and to the *Annulosa*.

The *Annuloida* are distinguished *by the presence of a distinct nervous system, and the possession of an alimentary canal which is entirely shut off from the general cavity of the body. A peculiar system of canals, usually communicating with the exterior, and termed the 'water-vascular,' or 'aquiferous,' system is present in all; and a true vascular apparatus is sometimes present. In none is the body of the adult composed of definite segments, or provided with 'bilaterally disposed successive pairs of appendages.'*

By Professor Allman the following definition has been given of the *Annuloida* or *Echinozoa*:—

'Animals composed of numerous merosomes' (body-segments) 'which are disposed radially round a longitudinal axis; always with a determinable, median, antero-posterior and dorso-ventral plane. A distinct body-cavity from which the alimentary canal is entirely shut off, and which, therefore, never communicates with the outer world through the mouth.'

The *Annuloida* are divided into two great classes, the *Echinodermata* and the *Scolecida*.

Class I. Echinodermata.

The members of this class are known commonly as Sea-urchins, Star-fishes, Brittle-stars, Feather-stars, Sea-cucumbers, &c., and the following are their leading characteristics. They are all animals which, in the adult condition, show a more or less distinctly radiate condition of their parts, especially of those around the mouth; whilst in their embryonic stages they are more or less distinctly bilaterally symmetrical. The external envelope of the body ('perisome') is either composed of numerous calcareous plates, articulated together, or of a coriaceous integument, in which calcareous granules and spicules are usually developed. In all adult *Echinoderms* there is a system of tubes, termed the 'ambulacral system,' which subserves locomotion, and usually communicates with the exterior. An alimentary canal is always present, and is completely shut off from the body-cavity. In many, if not in all, both neural and hæmal systems are developed. The nervous system in all the adult *Echinoderms* is a ring-like gangliated cord, which surrounds the œsophagus, and sends branches parallel to the radiating ambulacral canals.

The special features of the structure of the *Echinodermata* will be noticed under each order, but it will be as well to give here an abstract of Professor Huxley's description of the process of development in the members of the class. In the great majority, if not in all, of the *Echinodermata* the impregnated ovum is developed into a free-swimming, ciliated, ovoid embryo. Soon the cilia become restricted to one, two, or more bands, which are generally disposed transversely to the long axis of the body, and are in all cases bilaterally symmetrical. The parts of the body which support the cilia are usually developed into protuberances, or processes, which are symmetrically disposed upon the two sides of the body. 'The larvæ of *Asteridea* and *Holothuridea* are devoid of any continuous skeleton, but those of *Ophiuridea* and *Echinidea* possess a very remarkable, bilaterally symmetrical, continuous, calcareous skeleton, which extends into, and supports the processes of the body.' In this stage the larva form of the two orders last mentioned was described by Müller as a distinct animal, under the name of *Pluteus*, from its resemblance to a painter's easel. (See *fig.* 33, 1.)

An alimentary canal soon appears in the larva, forming a curve with an open angle towards the ventral surface of the organism. The parts of the alimentary canal consist of a mouth, gullet, globular stomach, and short intestine, with a distinct anal aperture; the whole being 'disposed in a longitudinal and vertical plane, dividing the larval body into two symmetrical halves.' Besides the digestive canal, no other organs have hitherto been discovered in these larvæ. In the further process of development, 'an involution of the integument takes place upon one side of the dorsal region of the body, so as to give rise to a cæcal tube, which gradually elongates inwards, and eventually reaches a mass of formative matter, or blastema, aggregated upon one side of the stomach. Within this, the end of the tube becomes converted into a circular vessel, from which trunks pass off, radially, through the enlarging blastema. The latter, gradually expanding, gives rise in the *Echinidea*, the *Asteridea*, the *Ophiuridea*, and the *Crinoidea* to the body-wall of the adult; the larval body and skeleton (when the latter exists), with more or less of the primitive intestine, being either cast off as a whole, or disappearing, or becoming incorporated with the secondary development, while a new mouth is developed in the centre of the ring formed by the circular vessel. The vessels which radiate from the latter give off diverticula to communicate with the cavities of numerous processes of the body—the so-called feet—which are the chief locomotive organs of the adult. The radiating and circular vessels, with all their appendages, constitute what is known as the "ambulacral system;" and in *Asterids* and *Echinids* this remarkable system of vessels remains in communication with the exterior of the body by canals, connected with perforated portions of the external skeleton—the so-called "madreporic canals" and "tubercles." In *Ophiurids* the persistence of any such communication of the ambulacral system with the exterior is doubtful, and still more so in *Crinoids*. In *Holothurids* no such communication obtains; the madreporic canals and their tubercles depending freely from the circular canal into the perivisceral cavity.'

By Professor Wyville Thomson the larva of the *Echinodermata* is termed the 'pseud-embryo;' since it leads a perfectly independent existence, and the true *Echinoderm* is usually developed out of a portion only of its substance.

The *Echinodermata* are divided into seven orders, viz. the *Crinoidea*, *Cystoidea*, *Blastoidea*, *Ophiuroidea*, *Asteroidea*, *Echinoidea* and *Holothuroidea*. Of these, the first is almost extinct and the two next are entirely so; they are really the lowest orders; but their structure will be better understood if the higher orders are considered first.

CHAPTER XIX.

ECHINOIDEA.

ORDER ECHINOIDEA.—The members of this order—commonly known as Sea-urchins—are characterised by the possession of a subglobose, discoidal, or depressed body, encased in a 'test,' or shell, which is composed of numerous, immovably connected, calcareous plates. The intestine is convoluted, and there is a distinct anus. The mouth is usually armed with calcareous teeth, and is always situated on the inferior surface of the body, but the position of the anal aperture varies. The larva is pluteiform and has a skeleton.

The 'test' of the *Echinoidea* is composed of numerous calcareous plates, firmly united to one another by their edges, and bearing different names according to their position aud function. In all recent members of the order the test is composed of twenty rows of these plates, arranged in ten alternating double rows of plates, which pass from the one pole of the animal to the other. Five of these double rows are composed of large plates, which are not perforated by any apertures (*fig.* 32); the zones formed by these imperforate plates being termed the 'inter-ambulacral areas.' The other five double rows of plates alternate regularly with the former, and are termed the 'ambulacral areas,' or 'poriferous zones.' Each of these zones is composed of two rows of small plates, which are perforated by minute apertures for the emission of the 'ambulacral tubes,' or 'tube-feet.' Growth of the test is carried on by additions made to the edge of each individual plate, by means of an organised membrane which passes between the sutures, where the plates come into contact with one another. The plates of the test are studded with large tubercles, which are more numerous on the inter-ambulacral areas than on the ambulacral, and are wanting on all the plates which do not belong to either area. These tubercles carry spines, used defensively and in locomotion, which are articulated to their apices by means of a sort of 'universal,' or 'ball-and-socket,' joint. Occasionally a small ligamentous band passes between the head of the tubercle and the centre of the concave articular surface of the spine, thus closely resembling the 'round ligament' of the hip-joint of man. Besides the main rows of plates just described, other calcareous pieces go to make up the test of an *Echinus*. The mouth is surrounded by a coriaceous buccal membrane, which contains a series of small calcareous pieces, known as the 'oral plates;' whilst a corresponding series of 'anal plates' is found in the membrane surrounding the opposite termination of the alimentary canal. In addition to these minute ossicula, at the summit of the test is the 'apical disc,' composed of the so-called genital and ocular plates (*fig.* 32, 3). The 'genital plates' are five large plates of a pentagonal form, each of which is perforated by the duct of an ovary or testis. One of the genital plates is larger than the others, and supports a spongy tubercle, perforated by many minute apertures, like the rose of a watering-pot, and termed the 'madreporiform tubercle.' The genital plates occupy the summits of the inter-ambulacral areas. Wedged in between the genital plates, and occupying the summits of the ambulacral areas, are five smaller, heart-shaped, or pentagonal plates, known as the 'ocular plates,' each being perforated by a pore for the reception of an 'ocellus' or 'eye.'

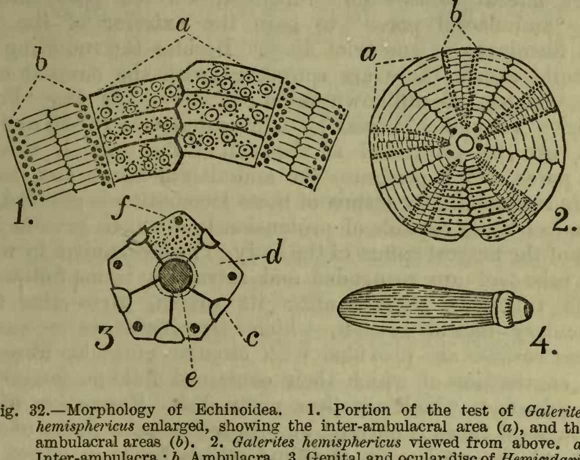


Fig. 32.—Morphology of Echinoidea. 1. Portion of the test of *Galerites hemisphericus* enlarged, showing the inter-ambulacral area (*a*), and the ambulacral areas (*b*). 2. *Galerites hemisphericus* viewed from above. *a.* Inter-ambulacra; *b.* Ambulacra. 3. Genital and ocular disc of *Hemicidaris intermedia*, enlarged. *c.* Ocular plate; *d.* Genital plate; *e.* Anal aperture; *f.* Madreporiform tubercle. 4. Spine of the same. (After Forbes.) The tubercles are mostly omitted on figs. 2 and 3 for the sake of clearness.

Besides the spines, which are sometimes of a very great length, the test often bears curious little appendages, called 'pedicellariæ,' and often supposed to be parasitic. Each of these consists of a stem, bearing two or three blades or claws, which snap together and close upon foreign objects, like the beak of a bird. Their action appears to be independent of the will of the animal, and their true function is not known.

Locomotion in the *Echinoidea* is effected by means of a singular system of contractile and retractile tubes, which constitute the 'ambulacral tubes,' or 'tube-feet,' and are connected with the 'ambulacral system' of aquiferous canals (*fig.* 33, 2). From the perforated 'madreporiform tubercle' on the largest of the genital plates, there proceeds a membranous canal, known as the 'stone,' or 'sand canal,' whereby water is conveyed from the exterior to a circular tube, surrounding the œsophagus, and constituting the centre of the water-vascular or ambulacral system. The function of the madreporiform tubercle appears to be that of permitting the ingress of water from the exterior, but of excluding any solid particles, which might be injurious. The 'circular canal,' surrounding the gullet, is situated between the nervous and blood-vascular rings, and gives off five branches—the 'radiating canals'—which proceed radially along the 'ambulacral areas' in the interior of the shell. In this course they give off numerous short lateral tubes—the 'tube-feet,'—which pass through the 'ambulacral pores' to gain the exterior of the test, and terminate in suctorial discs. Besides the radiating ambulacral canals, there are connected with the circular canal two vesicles, of unknown function, known as the 'Polian vesicles' (*ampullæ Polianæ*). The ambulacral tubes, or tube-feet, can be protruded at the will of the animal, through the pores which perforate the ambulacral areas, and can be again retracted. By means of these locomotion is effected, the tube-feet being capable of protrusion to a length greater than that of the longest spines of the body. The mechanism by which the tube-feet are protruded and retracted, is as follows:—Each tube-foot, shortly after its origin, gives rise to a secondary lateral branch, which terminates in a vesicle. These vesicles are provided with circular muscular fibres, by the contraction of which their contained fluid is forced into the tube-feet, which are thus protruded. Retraction of the ambulacral tubes is effected by proper muscular fibres of their own, which expel again the fluid which has been forced into them by the vesicles. According to Owen, the terminal sucker in each tube-foot of the *Echinus* is 'supported by a circle of five, or sometimes four, reticulate calcareous plates, which intercept a central foramen, and by a single, delicate, reticulated, perforate plate on the proximal side of the preceding group. The centre of the suctorial disc is perforated by an aperture conducting to the interior of the ambulacral tube-foot.' This perforation of the suctorial discs of the ambulacra, though affirmed by Valentin, is denied by Müller; and it is difficult to believe that it would not impair the functions of the feet in the act of protrusion.

The digestive system of the *Echinus* consists of a mouth, armed with five long, calcareous, rod-like teeth, which perforate five triangular pyramids, the whole forming a singular structure, known as 'Aristotle's lantern.' The mouth conducts by a pharynx and a tortuous œsophagus to a stomach, opening into a convoluted intestine, which winds round the interior of the shell, and terminates in a distinct anus. The mouth is always situated at the base of the test, and may be central, sub-central, or altogether excentric in position. The anus

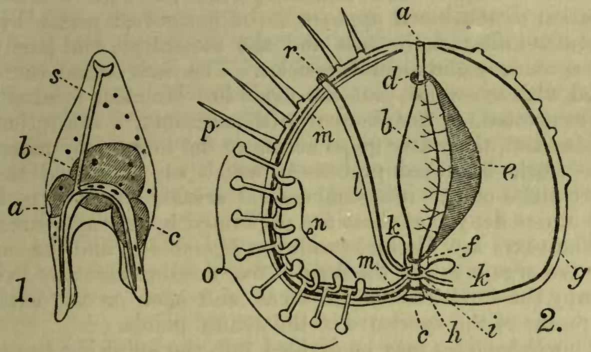


Fig. 33.—Morphology of Echinoidea. 1. Echinid larva. *a*. Mouth; *b*. Stomach; *c*. Intestine; *s*. Skeleton.
2. Diagram of Echinus. The spines and the ambulacra are represented over a small portion of the test; the vascular system is cross-shaded; the nervous system is represented by the black line. *a*. Anus; *b*. Stomach; *c*. Mouth; *d* and *f*. Vascular rings round the alimentary canal; *e*. Heart; *g*. Test; *h*. Nervous ring round the gullet; *i*. Ambulacral ring or 'circular canal' round the gullet; *k k*. Polian vesicles; *l*. Sand canal; *m m*. Radiating ambulacral canal; *n*. Secondary ambulacral vesicles; *o*. Ambulacra, or 'tube-feet;' *p*. Spines; *r*. Madreporiform tubercle.

varies considerably in its position, being usually situated within the apical disc, and surrounded by the genital and ocular plates. Sometimes, however, the anal aperture is without the apical disc, and is removed to some distance from the genital plates. The convolutions of the alimentary canal are attached to the interior of the test by a delicate mesentery; the surface of which, as well as that of the lining-membrane of the shell, is richly ciliated, and subserves the purposes of respiration.

The proper blood-vascular system (*fig*. 33, 2) consists of a central, fusiform, contractile vesicle, or heart. This gives off one vessel, which forms a ring round the intestine near the anus, and another which passes downwards, and forms a circle round the gullet, above the 'circular canal' of the ambulacral system. From the anal vessel proceed five arterial branches, which run along the ambulacral spaces, and return their blood by five branches, which run alongside of them in an opposite direction.

The nervous system consists of a ganglionated circular cord, which surrounds the gullet below, or superficial to, the 'circular canal' of the ambulacral system, and which sends five branches along the ambulacral spaces, in company with the radiating ambulacral canals.

There is no distinct respiratory organ, but the function of aëration of the blood appears to be performed partly by the vascular lining of the test and the mesentery, and partly by the secondary ambulacral vesicles. The perivisceral cavity is filled with sea-water, but the mode in which this is admitted, or renovated, is not known with certainty. According to Tiedemann, the water gains access to the interior by means of ten short, branched processes, which are attached to the extremities of the inter-ambulacral areas round the mouth; but others deny that these are perforated by any apertures.

The sexes are distinct in all the *Echinoidea*, and the reproductive organs are in the form of five membranous sacs, which occupy the inter-ambulacral areas, and open on the exterior by means of the apertures in the genital plates.

The *Echinoidea* may be divided into the following principal families :—

Fam. I. *Cidaridæ.*

Body nearly globular; mouth on the lower surface, central; anus opposite the mouth, situated within the apical disc, surrounded by the genital and ocular plates. Dental apparatus well developed. Ambulacra continuous from pole to pole (*ambulacra perfecta*).

Fam. II. *Clypeastridæ.*

Body discoid; mouth central, or sub-central; anus posterior, marginal, or infra-marginal. Genital plates with the madreporiform tubercle in their centre. Dental apparatus well developed. Ambulacra forming a five-rayed rosette on the dorsum of the test (*ambulacra circumscripta*).

Fam. III. *Spatangidæ.*

Body usually cordiform; mouth excentric. Anus posterior, and supra-marginal. No dental apparatus. Ambulacra circumscript.

CHAPTER XX.

ASTEROIDEA AND OPHIUROIDEA.

ORDER ASTEROIDEA (*Stellerida*). — This order comprises the ordinary star-fishes, and is defined by the following characters :—The body is star-shaped, and consists of a central body or 'disc,' surrounded by five or more lobes, or 'arms,' which radiate from the body, are hollow, and contain prolongations of the viscera. The body is not enclosed in an immovable box, as in the *Echinoidea*, but the integument ('perisome') is coriaceous, and is strengthened by irregular calcareous plates, or studded by calcareous spines. No dental apparatus is present. The mouth is inferior, and central in position; the anus either absent or dorsal. The ambulacral tube-feet are protruded from grooves on the under surface of the rays. The larva is vermiform and has no skeleton.

The skeleton of the *Asteroidea* is composed of a vast number of small calcareous plates, or ossicula, united together by the coriaceous perisome, so as to form a species of chain-armour. Besides these, the integument is abundantly supplied with spines, tubercles, and 'pedicellariæ.' The upper surface of a star-fish corresponds to the combined inter-ambulacral areas of an *Echinus*, and exhibits the aperture of the anus (when present), and the 'madreporiform tubercle,' which is situated near the angle between two rays. The inferior or ventral surface corresponds to the ambulacral areas of an *Echinus*, and exhibits the mouth and ambulacral grooves.

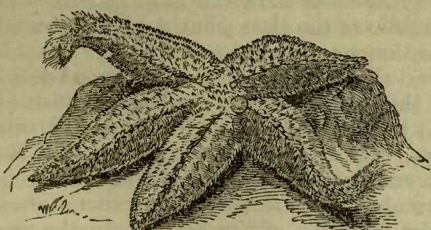


Fig. 34.—Asteroidea. *Uraster rubens*, the common Star-fish or Cross-fish.

The mouth is central in position, and is not provided with teeth; it leads, by a short gullet, into a large stomach, from which a pair of sacculated diverticula are prolonged into each ray. A distinct intestine and anus may, or may not, be present; but the anus is sometimes wanting.

The ambulacral system is essentially the same as in the *Echinoidea*, and is connected with the exterior by means of the 'madreporiform tubercle,' or 'nucleus,' two, three, or more of these being occasionally present. The ambulacral tube-feet are arranged in two or four rows, along grooves in the under surface of the arms.

The blood-vascular system consists, as in the *Echinus*, of two circular vessels, one round the intestine, and one round the gullet, with a dilated tube, or heart, intervening between them. There are no distinct respiratory organs, but the surfaces of the viscera are abundantly supplied with cilia, and doubtless subserve respiration; the sea-water being freely admitted into the general body-cavity by means of numerous contractile ciliated tubes, which project from the dorsal surface of the body, and are perforated at their free extremities. (Owen.)

The nervous system consists of a gangliated cord, surrounding the mouth, and sending filaments to each of the rays. At the extremity of each ray is a pigment-spot, corresponding to one of the ocelli of an *Echinus*, and, like it, supposed to be a rudimentary organ of vision. The eyes are often surrounded by circles of movable spines, called 'eye-lids.'

The generative organs are in the form of ramified tubes, arranged in pairs in each ray, and emitting their products either into the surrounding medium, by means of efferent ducts which open round the mouth, or into the general body-cavity, by dehiscence, the external medium in this latter case being ultimately reached through the respiratory tubes. In their development, the *Asteroidea* show the same general phenomena as are characteristic of the class; but the larvæ are not provided with any continuous endoskeleton.

The general shape of the body varies a good deal in different members of the order. In the common star-fish (*Uraster rubens*, *fig.* 34) the disc is small, and is furnished with long, finger-like rays, usually five in number. In the *Solasters* the disc is large and well marked, and the rays are from twelve to fifteen in number, and are narrow and short (about half the length of the diameter of the body). In the *Goniasters* the body is in the form of a pentagonal disc, flattened on both sides; the true 'disc' and rays being only visible on the under surface of the body. In none of the true star-fishes, however, are the arms ever sharply separated from the disc, as in the *Ophiuroidea*, but they are always an immediate continuation of it.

The order *Asteroidea* has been divided by Dr. Gray as follows:—

ORDER ASTEROIDEA.

Section a. Ambulacra with four rows of feet.

Family 1. *Asteriadæ.* Dorsal wart simple.

Section b. Ambulacra with two rows of feet.

Family 2. *Astropectinidæ.* Back flattish, netted with numerous tubercles, crowned with radiating spines at the tip, called 'paxillæ.'

Family 3. *Pentacerotidæ.* Body supported by roundish or elongated pieces, covered with a smooth or granular skin, pierced with minute pores between the tubercles.

Family 4. *Asterinidæ.* Body discoidal or pyramidal; sharp-edged; skeleton formed of flattish, imbricate plates; dorsal wart single, rarely double.

ORDER OPHIUROIDEA.—This order comprises the small but familiar group of the 'Brittle-stars' and 'Sand-stars,' often considered as belonging to the *Asteroidea*, to which they are nearly allied. The body in the *Ophiuroidea* (*fig.* 35) is discoidal, and is either naked, or is covered with granules, spines, or scales. From the body—which contains all the viscera—proceed long, slender arms, which may be simple or branched, but which do not contain any prolongations from the stomach, nor have their under surface excavated into ambulacral grooves. The arms, in fact, are not simple prolongations of the body, as in the *Asteroidea*, but are special appendages, superadded for locomotive and prehensile purposes. Each arm is enclosed by four rows of calcareous plates, one on the dorsal surface, one on the ventral surface, and two lateral. In the centre of each arm is a chain of quadrate ossicles, forming a central axis, and between this axis and the row of ventral plates is placed the ambulacral vessel. The mouth is situated in the centre of the inferior surface of the body, is provided with a masticatory apparatus, and is surrounded by tentacles. It opens directly into a ciliated stomach, which is not continued into an intestine, the mouth serving as an anal aperture. The reproductive organs are situated near the bases of the arms, and open by orifices on the ventral surface of the body or in the interbrachial areas.

It is very questionable whether the ambulacral system in the adult *Ophiuroidea* communicates with the exterior; its place as a locomotive apparatus being taken by the arms.

The larva of the *Ophiuroidea* is pluteiform and is furnished with a continuous endoskeleton; and in some, as in *Ophiolepis squamata*, the echinoderm-body appears within the larva, when the latter has attained but a very imperfect degree of development.

In *Euryale* the body is in the form of a sub-globose disc with five obtuse angles, and the arms are prehensile. In *Asterophyton*, the Medusa-head star, the arms are divided from the base, first dichotomously, and then into many branches. In

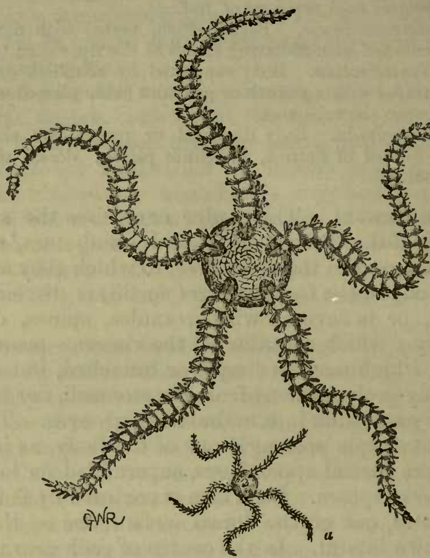


Fig. 35.—Ophiuroidea.—*Ophiocoma neglecta.*

Ophiura, the sand-star, the arms serve for reptation (creeping), and are undivided, often exceeding the diameter of the disc many times in length.

The order *Ophiuroidea* may be divided into two families, as follows:—

Family 1. *Ophiuridea.*
Genital fissures two or four in number. Arms five, always simple.

Family 2. *Asterophydiæ.*
Genital fissures ten in number. Arms five, simple or branched.

CHAPTER XXI.

CRINOIDEA, CYSTOIDEA AND BLASTOIDEA.

ORDER CRINOIDEA.—The members of this order are *Echinodermata*, in which *the body is fixed, during the whole or a portion of the existence of the animal, to the sea-bottom by means of a longer or shorter, jointed, and flexible stalk.* The body is distinct, composed of articulated calcareous plates, bursiform, or cup-shaped, and provided with solid arms, which are primarily from five to ten in number, are independent of the visceral cavity, and are grooved on their upper surfaces for the ambulacra. (The position of the body being reversed, the *upper* surface is *ventral*; whilst the *dorsal* surface is *inferior*, and gives origin to the pedicle.) The mouth is central, and looks upwards, an anal aperture being sometimes present, sometimes absent. The ovaries are situated beneath the skin in the grooves on the ventral surfaces of the arms or pinnules. The arms are furnished with numerous lateral branches or 'pinnulæ.' The embryo is 'free and ciliated, and develops within itself a second larval form, which becomes fixed by a peduncle.'—(Huxley.)

Of those *Crinoidea* which are permanently fixed to the sea-bottom by a jointed pedicle, there exist but one or two living forms, of which the best known is the *Pentacrinus Caput-Medusæ.* In this type of the *Crinoidea*—largely represented in past geological epochs—the body is composed of a series of calcareous plates, united together so as to form a cup, or 'calyx,' the bottom of which is continued into a 'column,' or pedicle, composed of a series of calcareous joints or articulations, whereby the animal is fixed to some foreign body. The upper part of the calyx is roofed over by a series of calcareous plates, and is perforated by the apertures of the mouth and anus, the latter being sometimes absent. In the recent species the mouth is central, and there is a distinct anus at one side. The margin of the calyx gives origin to the arms, which are grooved on their upper (or ventral) surfaces for the ambulacra. In the living *Crinoids* the ambulacral grooves are continued along the upper surface of the calyx to the mouth. In the Palæozoic *Crinoids* there is only a single opening on the upper surface of the calyx, which is sometimes central and sometimes lateral, and which serves both as a mouth and anus. In many cases this aperture is level with the surface of the calyx, but in many species it is placed at the summit of a long, projecting tube, which is termed the 'proboscis.' The ambulacral grooves in the Palæozoic *Crinoids* are found on the ventral surfaces of the arms, as in the living species; but instead of being continued over the surface of the body to the mouth, they stop short at the bases of the arms, where they gain access to the interior of the calyx by a series of special apertures.—(Billings.)

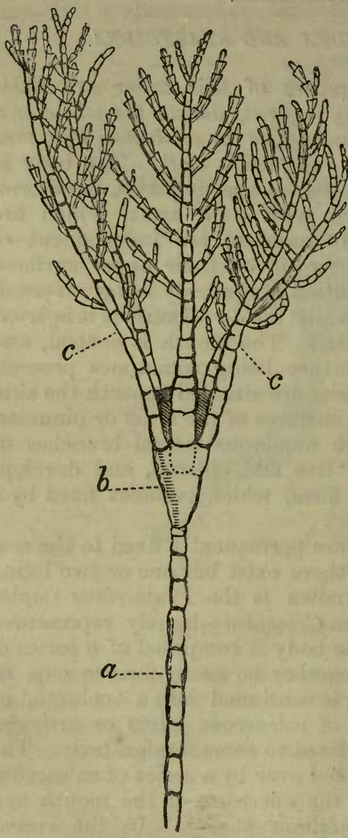


Fig. 36.—Crinoidea: *Rhizocrinus Lofotensis*, a living Crinoid (after Wyville Thomson), four times the natural size. *a*. Stem. *b*. Calyx. *c c*. Arms.

More recently a stalked Crinoid has been discovered in the Atlantic and North Sea, and has been described under the name of *Rhizocrinus Lofotensis*. The chief interest of this form is the fact that it belongs to a group of the *Crinoidea* hitherto believed to be exclusively confined to the Mesozoic Rocks, viz. the *Apiocrinidæ* or 'Pear-encrinites.' In fact, *Rhizocrinus* is very closely allied to the Cretaceous genus *Bourgueticrinus*, and it may even be doubted if it is generically separable from it (*fig*. 36).

In the second type of the *Crinoidea* — represented in our seas by the *Comatula*, or Feather-star—the animal is not permanently fixed, but is only attached by a stalk when young, in which condition it was described as a distinct species, under the name of *Pentacrinus Europæus*. In its adult condition, however, the *Comatula* is free, and consists of a pentagonal disc, which gives origin to ten slender arms, which are fringed with many marginal pinnulæ or 'cirri.' The mouth and anus are on the ventral surface of the disc, which in this case is again the inferior surface, since the animal creeps about by means of its pinnated arms. The mouth is central in position, and the anus, which in some species forms a tubular projection, is situated on one side. Both the arms and the lateral pinnulæ are grooved on their ventral surfaces for the ambulacra; and the pinnules also serve for the support of the reproductive organs. It is extremely doubtful if the ambulacral system, in the adult, has any communication with the exterior.

ORDER CYSTOIDEA (*Cystidea*).—The members of this order are all extinct,* and are entirely confined to the Palæozoic period. The body (*fig.* 37) was more or less spherical, and was protected by an external skeleton, composed of numerous polygonal calcareous plates, accurately fitted together, and enclosing all the viscera of the animal. The body was in most cases permanently attached to the sea-bottom by means of a jointed calcareous 'column,' or pedicle, but this was much shorter than in the majority of *Crinoids*. Upon the upper surface of the body were two, sometimes three apertures, the functions of which have been a matter of considerable controversy. One of these is lateral in position, is defended by a series of small valvular plates, and is believed by some to be the mouth, whilst by others it is asserted to have been an ovarian aperture. The second opening is central in position, and is believed by Mr. Billings to be the 'ambulacral orifice,' as it is always in the centre of the arms, when these are present. The third aperture is only occasionally present, and doubtless discharged the functions of an anus.

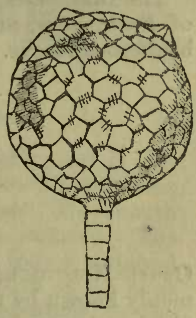


Fig. 37. — Cystidea. *Echinosphærites aurantium*, a Cystidean from the Bala Limestone (Lower Silurian).

In some *Cystoidea* there were no arms, properly speaking, but only small pinnulæ. In a second section true arms were present, but these were bent backwards, and were immovably soldered down to the body. In one single species (*Comarocystites punctatus*, Billings) the development has gone further, the arms being free, and provided with lateral pinnulæ, as in the true *Crinoids*.

Many Cystideans are likewise provided with a system of pores, or fissures, penetrating the plates of the body, and

* Recently Professor Löven has described a singular Australian Echinoderm as being most closely allied to, if not truly referable to, the order *Cystoidea*. He has named this curious form *Hyponome Sarsi*, and believes it to be nearly related to the Cystidean genus *Agelacrinites*.

usually arranged in definite groups. These groups are termed 'pectinated rhombs,' but their exact function is entirely unknown.

ORDER BLASTOIDEA.—The members of this order, like those of the preceding, are all extinct, and are entirely confined to the Palæozoic period. The body was fixed to the bottom of the sea by means of a short jointed pedicle; it was globular or oval in shape, and composed of solid polygonal calcareous plates, firmly united together, and arranged in five inter-ambulacral and as many ambulacral areas. (These ambulacral areas are termed by M'Coy 'pseud-ambulacra,' upon the belief that they were not pierced for tube-feet, but that they carried a double row of little jointed tentacles or arms.) The ambulacral areas are petaloid in shape, having a deep furrow down the centre, and striated transversely. They converge to the mouth, which is superior and central in position, and is surrounded by five ovarian apertures. No arms are present.

The *Blastoidea* are known more familiarly under the name of *Pentremites*, and they occur most commonly in the Carboniferous Rocks.

CHAPTER XXII.

HOLOTHUROIDEA.

ORDER HOLOTHUROIDEA.—The members of this order are commonly known by the name of 'sea-cucumbers,' 'trepangs,' or 'bèches-de-mer,' and are the most highly organised of all the *Echinodermata.* The body is elongated and vermiform, and is not provided with a distinct test, but is enclosed in a coriaceous skin, usually containing scattered calcareous granules or spicules. The ambulacral tube-feet, when present, are usually disposed in five rows, which divide the body into an equal number of longitudinal segments or lobes. The mouth is surrounded by a circlet of feathery tentacles, and an anus is situated at the opposite extremity of the body. There is a long, convoluted intestine. A special respiratory, or water-vascular, system is usually developed, in the form of a system of arborescent tubes, which admit water from the exterior. The larva is vermiform, and has no skeleton (*fig.* 38).

In the *Holothuriæ* proper, locomotion is effected by means of rows of ambulacral tube-feet; but in the *Synaptidæ* there are no ambulacra, and the animal moves by means of anchor-shaped spicula, which are scattered in the integument. When developed, the ambulacral system consists of a 'circular canal' surrounding the mouth, bearing one or more 'Polian vesicles,' and giving off branches to the tentacula; and of five 'radiating canals' which run down the interspaces between the great longitudinal muscles. These radiating canals give off the tube-feet and their secondary vesicles, just as in the *Echinus*. There is also a 'sand-canal,' which arises from the circular canal, and is terminated by a madreporiform tubercle; but this, instead of opening on the exterior, hangs down freely in the perivisceral cavity.

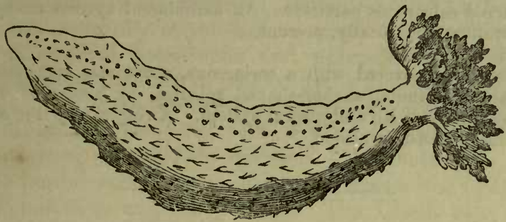


Fig. 38.—*Cucumaria communis.* (After Forbes.)

The mouth in *Holothuria* is situated anteriorly, and is surrounded by a beautiful fringe of branched, retractile tentacles, which arise from a ring of calcareous plates. The mouth opens into a pharynx, which conducts to a stomach. The intestine is long and convoluted, and opens into a terminal dilatation, termed the 'cloaca,' which serves both as an anus and as an aperture for the admission of sea-water to the respiratory tubes. From the 'cloaca' arise two branched and arborescent tubes, the terminations of which are cæcal. These run up towards the anterior extremity of the body, and together constitute the so-called 'respiratory tree.' They are highly contractile, and they perform the function of respiratory organs, sea-water being admitted to them from the cloaca. The nervous system consists of a cord, surrounding the gullet, and giving off five branches, which run alongside of the radiating ambulacral canals. The generative organs are in the form of long, ramified, cæcal tubes, which open externally by a common aperture, situated near the mouth. There is, thus, no trace of that radial symmetry which is observed in the arrangement of the reproductive organs in the other orders of the *Echinodermata*.

The skin in the *Holothuriæ* is highly contractile, and the body is provided with powerful longitudinal and circular muscles.

In *Synapta* there is no ambulacral system, nor respiratory tree. Locomotion is effected by means of little, anchor-shaped, calcareous spicules, placed upon little papillæ of the integument. Respiration is effected in the abdominal cavity, into which the water is admitted by five openings between the tentacles.

The order *Holothuroidea* may be divided into the following two families:—

Family I. *Holothuridæ.*

Body free, cylindrical, with a coriaceous integument containing scattered calcareous particles. An ambulacral system always, and a respiratory tree usually, present.

Family II. *Synaptidæ.*

Body free, covered with a coriaceous, sometimes soft, integument, containing minute, anchor-shaped spicules, by means of which the animal moves. No ambulacral system. A respiratory tree sometimes present, sometimes absent.

CHAPTER XXIII.

DISTRIBUTION OF ECHINODERMATA IN SPACE AND TIME.

DISTRIBUTION OF ECHINODERMATA IN SPACE.—The *Crinoidea* are represented by very few forms in recent seas, and these have a very local distribution. The *Comatula* is the commonest, and occurs abundantly on some parts of our coasts. The *Pentacrinus Caput-Medusæ* is exclusively confined, as far as is known, to the Caribbean Sea. *Rhizocrinus Lofotensis* has been dredged on the coast of Norway, and a form believed to be the same has been found in the Gulf of Mexico.

The *Asteroidea*, *Ophiuroidea*, and *Echinoidea* are represented in almost all seas, whether in tropical or temperate zones, some occurring very far north. The *Holothuroidea* have their metropolis in the Pacific Ocean, occurring abundantly on the coral reefs of the Polynesian Archipelago. One species is collected in large numbers, and is exported to China, where it is regarded as a great delicacy.

DISTRIBUTION OF ECHINODERMATA IN TIME.—Numerous remains of *Echinodermata* occur in most sedimentary rocks, beginning with the base of the Lower Silurian Rocks, and extending up to the recent period. The two orders *Cystoidea* and *Blastoidea*, which are the most lowly organised of the entire class, are exclusively Palæozoic; and the *Crinoidea* are mostly referable to the same epoch. The more highly organised *Asteroidea* and *Ophiuroidea* commenced to be represented in the Silurian period; but the *Echinoidea*, with a single exception, have no representative earlier than the Carboniferous Rocks. The following exhibits the geological distribution of the different orders of the *Echinodermata* in somewhat greater detail:—

1. Crinoidea.*—The *Crinoidea* attained their maximum in the Palæozoic period, from which time they have gradually diminished down to the present day. As has already been described, the Palæozoic *Crinoidea* differ in some important particulars from those which succeeded them. The order is well represented in the Silurian, Devonian, and Carboniferous Rocks, but especially in the latter; many Carboniferous limestones (Crinoidal limestones and entrochal marbles) being almost entirely made up of the columns and separate joints of Crinoids. In the Secondary Rocks Crinoids are still abundant. In the Trias the beautiful 'Stone-lily' (*Encrinus liliiformis*) is peculiar to its middle division (Muschelkalk). In the Jurassic period occur many species of *Apiocrinus* (Pear-encrinite), *Pentacrinus* and *Extracrinus*. The Chalk also abounds in Crinoids, amongst which is a remarkable unattached form (the Tortoise-encrinite or *Marsupites*).

Of the non-pediculate *Crinoidea*, which are a decided advance upon the stalked forms, there are few traces; but remains of *Comatula* have been discovered in the lithographic slate of Solenhofen (Oolite) and in the Chalk.

2. Blastoidea.—The *Blastoidea*, or Pentremites, are entirely Palæozoic, and attain their maximum in the Carboniferous Rocks, some beds of which in America are known as the Pentremite Limestone, from the abundance of these organisms. They are, however, also found in the Silurian and Devonian Rocks.

3. Cystidea.—These, like the preceding, are entirely Palæozoic; but they are, as far as is yet known, exclusively confined to the Upper Cambrian and Silurian Rocks, being especially characteristic of the horizon of the Bala Limestone. Forms

* As regards the calyx of the fossil *Crinoidea* the following terms are employed to designate its different parts. The base of the cup, or calyx, is termed the 'pelvis,' and it is made up of five, four, or sometimes three, plates, which are termed the 'basals.' To the 'basals' succeed two or three rows of plates, which are termed respectively the 'primary radials,' 'secondary radials' and 'tertiary radials,' according to their distance from the basals. The axillary radials, which are the furthest removed, give origin to the arms, and are occasionally called the 'scapulæ' (for this reason), whilst the primary and secondary radials are called the 'costæ.'

supposed to be Cystideans have been described from the Devonian Rocks, but their true nature is doubtful.

4. Asteroidea.—These have a very long range in time, extending from the Lower Silurian period up to the present day. In the Silurian Rocks the genera *Palæaster*, *Stenaster*, *Palæodiscus* and *Petraster* are among the more important, the greater number of forms being Upper Silurian. The next period in which star-fishes abound is the Oolitic (Mesozoic); the more important genera being *Uraster*, *Luidia*, *Astropecten*, *Plumaster* and *Goniaster*, some of which have survived to the present day. Many star-fishes occur, also, in the Cretaceous Rocks, the genera *Oreaster*, *Goniodiscus* and *Astrogonium* being among the more noticeable. In the Tertiary Rocks few star-fishes are known to occur, but *Goniaster* and *Astropecten* are represented in the London Clay (Eocene).

5. Ophiuroidea.—The 'brittle-stars' are represented in the Silurian Rocks by the single genus *Protaster*. In the Oolitic, Cretaceous, and Tertiary Rocks several genera of *Ophiuroidea* are known; some being extinct, whilst others (such as *Ophioderma*, *Ophiolepis*, and *Ophiocoma*) still survive at the present day.

6. Echinoidea.—This order is represented in the Palæozoic Rocks by a single aberrant family; but it is numerously represented in the Mesozoic and Kainozoic periods.

For the Palæozoic *Echinoidea* the formation of a separate sub-order has been proposed by Professor M'Coy under the name of *Perischoechinidæ*; since they differ in some fundamental points from all the other known members of the order. They are composed of *more than twenty* rows of calcareous plates, divided into five ambulacral and five inter-ambulacral areas. The five ambulacra are continuous from pole to pole, and are surmounted dorsally by the ocular plates. The five inter-ambulacra are composed, each, of three, five, or more rows of plates, and are surmounted dorsally by the ovarian plates. The two genera *Archæocidaris* and *Palæchinus* comprise all the known forms of the family, the former being entirely confined to the Carboniferous Limestone, whilst the latter occurs also in the Upper Silurians.

The Secondary and Tertiary *Echinoidea* resemble those now living in being composed of not more than twenty rows of calcareous plates. The Oolitic and Cretaceous Rocks are especially rich in forms belonging to this order, many genera being peculiar; but the number of forms is too great to permit of any selection.

7. Holothuroidea.—This order, comprising, as it does, soft-bodied animals, can hardly be said to be known as occurring

in the fossil condition. Some calcareous plates and spicules, supposed to belong to a *Holothurid*, have, however, been described as occurring in the Secondary Rocks, and the shield of *Psolus* has been found in Post-tertiary deposits in Bute.

CHAPTER XXIV.

SCOLECIDA.

CLASS II. SCOLECIDA.—This class was proposed by Professor Huxley for the reception of the remaining members of the *Annuloida*, comprising the *Rotifera*, the *Turbellaria*, the *Trematoda*, the *Tæniada*, the *Nematoidea*, the *Acanthocephala*, and the *Gordiacea*. Of these the *Rotifera* stand alone, whilst the *Turbellaria*, *Trematoda*, and *Tæniada* constitute the old division of the *Platyelmia* (Flat Worms), and the *Nematoidea*, *Acanthocephala*, and *Gordiacea* make up the old *Nematelmia* (Round Worms or Thread-worms). For some purposes these old divisions are sufficiently convenient to be retained, though they are of little scientific value. The term *Entozoa* has acquired such a general currency, that it is necessarily employed occasionally, but it has been used in such widely different senses by different writers, that it would be almost better to discard it altogether. It certainly cannot be used as synonymous with *Scolecida*, many of these not being parasitic at all. It will, therefore, be employed here, in a restricted sense, to designate those orders of the *Scolecida*, which are internal parasites, comprising the *Trematoda*, *Tæniada*, *Nematoidea* (in part), *Acanthocephala*, and *Gordiacea*. The *Turbellaria* and *Rotifera*, with a section of the *Nematoidea*, lead a free existence, and are not parasitic within other animals.

The *Scolecida* are defined by the possession of a 'water-vascular system,' consisting of 'a remarkable set of vessels which communicate with the exterior by one, or more apertures situated upon the surface of the body, and branch out, more or less extensively, into its substance.'—(Huxley.) No proper vascular apparatus is present, and the nervous system (when present) 'consists of one, or two, closely approximated ganglia.' The habits and mode of life of the different members of the *Scolecida* are so different, that no other character, save the above, can be predicated which would be common to the entire class, and would not be shared by some other allied division.

DIVISION I. PLATYELMIA.—This section includes those *Scole-*

cida which possess a more or less flattened body, usually somewhat ovate in shape, and not exhibiting anything like distinct segmentation. The division includes two parasitic orders—the *Tæniada* and the *Trematoda*—and one non-parasitic order, viz. the *Turbellaria.* A sub-order, however, of this last, the *Nemertidæ*, does not conform to the above definition; but their other characters are such as to forbid their separation.

ORDER I. TÆNIADA (*Cestoidea*).—This order comprises the internal parasites, called Tape-worms (Cestoid worms), and the old order of the 'Cystic worms' (Cystica); the latter being now known to be merely immature forms of the Tape-worms.

In their mature condition, the *Tæniada* (*see fig.* 39) are always found inhabiting the alimentary canal of some warm-blooded vertebrate animal; and they are distinguished by their great length, and by being composed of a number of flattened joints, or articulations. These joints are not, however, an example of true segmentation, nor do they really constitute the Tape-worm; the true animal being found in the small, rounded, anterior extremity, the so-called 'head,' whilst the joints are simply hermaphrodite, generative segments, which the 'head' throws off by a process of gemmation. The 'head' (*fig.* 39, 3), which constitutes the real Tape-worm, is a minute, rounded body, which is furnished with a circlet of hooks, or suckers, or both, whereby the parasite is enabled to maintain its hold upon the mucous membrane of the intestines of its host. No digestive organs of any kind are present, not even a mouth; and the nutrition of the animal is entirely effected by imbibition. The nervous system consists of two small ganglia, which send filaments backwards. The 'water-vascular system' consists of a series of long vessels which run down each side of the body, communicating with one another at each articulation by means of a transverse vessel, and opening in the last joint into a contractile vesicle. It, thus, appears that all the joints are organically connected together. Whilst the 'head' constitutes the real animal, it, nevertheless, contains no reproductive organs, and these are developed in the joints or segments (*fig.* 39, 4), which are produced from the head posteriorly by budding. After the first joint, each new segment is intercalated between the head and the segment, or segments, already formed; so that the joints nearest the head are those latest formed, and those furthest from the head are the most mature. Each segment, when mature, contains both male and female organs of generation, and is, therefore, sexually perfect. To such a single segment the term 'proglottis' is applied, from its resemblance in shape to the tip of the tongue. The ovary is a branched tube, which occupies the greater part of the proglottis, and opens, along with the efferent duct of the male organ, at a common papilla, which is perforated by an aperture, termed the 'generative pore.' The position of this pore varies, being placed in the centre of one of the lateral margins of the proglottis in the common Tape-worm (*Tœnia solium*), but being situated upon the flat surface of the segment in the rarer *Bothriocephalus latus.* These two elements, namely the minute head, with its hooklets and suckers, and the aggregate of the joints, or proglottides, together compose what is commonly called a 'Tape-worm,' such as is found in the alimentary canal of man, and of many animals. The length of this composite organism varies from a few inches to several yards.

Singular as is the composition of the mature Tape-worm, still more extraordinary are the phenomena observed in its development, of which the following is a brief account:—

'Proglottides,' or the sexually mature segments of a Tape-worm, are only produced within the alimentary canal of man, or of some other warm-blooded vertebrate. The development of the ova which are contained in the proglottides, cannot, however, be carried out in this situation; hence the comparative harmlessness of this parasite, and hence the name of 'solitary worm,' which is sometimes applied to it. For the production of an embryo, it is necessary that the ovum should be swallowed by some animal other than the one inhabited by the mature Tape-worm. If this does not take place the fecundated ovum is absolutely unable to develop itself. To secure this, however, the dispersion of the ova is provided for by the expulsion of the ripe proglottides from the bowel, all their contained ova having been previously fertilised. After their discharge from the body, the proglottides decompose, and the ova are liberated (*fig.* 39, 1), when they are found to be covered by a capsule which protects them from all ordinary mechanical, and even chemical, agencies, which might prove injurious to them. In this stage, the embryo is often so far developed within the ovum that its head may be recognised by its possession of three pairs of siliceous hooklets. For further development, it is now necessary that the ovum be swallowed by some warm-blooded vertebrate, and should thus gain access to its alimentary canal. When this takes place, the protective capsule or covering of the microscopically minute ovum is ruptured, either mechanically during mastication, or chemically by the action of the gastric juice; and the embryo is thus liberated. The liberated embryo is now called a 'proscolex,' and consists of a minute vesicle, which is provided with three pairs of siliceous spines, fitted for boring through the tissues of its host. Armed with these, the proscolex perforates the wall of the stomach, and may either penetrate some contiguous organ, or may gain access to some blood-vessel, and be conveyed by the blood to some part of the body, the liver being the one most likely.

Having by one of these methods reached a suitable resting-place, the proscolex now proceeds to surround itself with a cyst, and to develop a vesicle, containing fluid, from its posterior extremity, when it is called a 'scolex' (*fig.* 39, 2). In some of the *Tæniada* the scolices are called 'hydatids,' and it is these, also, which constituted the old order of the 'Cystic Worms.' When thus encysted within the tissues of an animal, the 'scolex' consists simply of a tænioid head, with a circlet of hooklets and four 'oscula' or suckers, united by a contracted neck to a vesicular body. It contains no reproductive organs, or, indeed, organs of any kind, and can not attain any further stage of development, unless it be swallowed and be taken for the second time into the alimentary canal of a warm-blooded vertebrate. It may increase, and produce fresh scolices; but this takes place simply by a process of gemmation. In some cases, however, a very partial and limited development does actually take place in the scolex prior to this change of abode, but this is an exceptional occurrence. In these cases the 'neck' of the scolex becomes partially segmented, so that it comes to resemble an imperfectly developed *Tænia*, and is called a 'strobila-embryo.' The series of changes, however, whereby the scolex is converted into the 'strobila,' or adult tape-worm, can not be carried out unless the scolex gain access to the alimentary canal of a warm-blooded vertebrate. In this case, the scolex attaches itself to the mucous membrane of the intestinal tube by means of its cephalic hooklets (when these are present) and suckers. The caudal vesicle now drops off, and the scolex is thus converted into the 'head' of the tape-worm. Gemmation then commences from its posterior extremity, the first segments being immature. As the first-formed joints, however, are pushed further from the head by the constant intercalation of fresh articulations, they become sexually mature, thus constituting the 'proglottides' of the adult Tape-worm with which the cycle began. To the entire organism, with its 'head,' and its mature and immature joints ('proglottides'), the term 'strobila' is now applied.

In the development, therefore, of the Tape-worm we have to remember the following stages:—

1. The *ovum*, set free from a generative joint, or proglottis.

2. The *proscolex*, or the minute embryo which is liberated from the *ovum*, when this latter has been swallowed by any warm-blooded vertebrate.

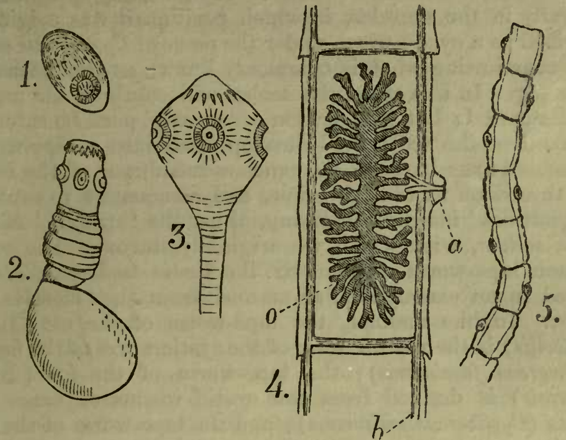


Fig. 39.—Morphology of Tæniada. 1. Ovum containing the embryo in its leathery case. 2. *Cysticercus longicollis*. 3. 'Head' of adult *Tœnia solium* enlarged, showing the hooklets and cephalic suckers. 4. A single generative joint, or proglottis, magnified, showing the dendritic ovary (*o*), the generative pore (*a*), and the water-vascular canals (*b*). 5. A portion of a Tape-worm (strobila), showing the alternate arrangement of the generative pores.

3. The *scolex*, or the more advanced, but still sexually imperfect, embryo, into which the *proscolex* develops, when it has encysted itself within the tissues of its host. (Under this head come the so-called 'Cystic Worms.')

4. The *strobila*, or adult Tape-worm, into which the *scolex* develops itself, when received into the alimentary canal of a warm-blooded vertebrate. The strobila is constituted by the 'head,' and by a number of immature and mature generative segments or joints, termed the 'proglottides.'

The subject will, perhaps, be more clearly understood by following the development of one of the common Tape-worms of man, viz. the *Tœnia solium*. Commencing with an individual who is already suffering from the presence of this parasite, one of the most distressing symptoms of the case is found to be the escape of the joints of the animal from the bowel. These joints are the ripe 'proglottides,' containing the fecundated ova. When the ova—which are microscopic in size—are liberated by the decomposition of the proglottis, they may gain access to water, or be blown about by the wind. In many ways, it is easy to understand how one of them may be swallowed by a pig. When this occurs a 'proscolex' is liberated from the ovum, and bores its way through the walls of the stomach, to become a 'scolex.' It now takes up its abode, generally in the muscles, in which position it was originally described as a cystic worm under the name of *Cysticercus cellulosæ*, constituting what is commonly known as the 'measles' of the pig. In this state, the scolex will continue for an indefinite period; but if a portion of 'measly' pork be eaten by a man, then the scolex will develop itself into a tape-worm. The scolex fixes itself to the mucous membrane of the intestine, throws off its caudal vesicle, and commences to produce 'proglottides' instead, becoming, thus, the 'strobila' of the *Tænia solium*, with which we originally started. The other common tape-worm of man, viz. the *Tænia mediocanellata*, is derived in an exactly similar manner from the 'measles' of the ox. In like manner, the tape-worm of the cat (*Tænia crassicollis*) is the mature form of the cystic worm of the mouse (*Cysticercus fasciolaris*); the tape-worm of the fox (*Tænia pisiformis*) is derived from the cystic worms of hares and rabbits (*Cysticercus pisiformis*); and the tape-worm of the dog (*Tænia serrata*) is the developed form of the *Cœnurus cerebralis* of the sheep, the cystic worm which causes the 'staggers' in the latter animal.

Besides tape-worms, however, man is liable to be affected with 'scolices,' which are the larvæ of the tape-worms of other animals. Thus, what are professionally called 'hydatids' in the human subject, are really the scolices of the tape-worm of the dog. The disease is indicated by the presence of the so-called 'hydatid-tumour,' which consists of a strong membranous cyst—the 'hydatid' proper—situated in some solid organ, most commonly the liver, and filled with a watery fluid. To the interior of the cyst are attached numerous minute scolices, many others also floating freely in the contained fluid. These 'Echinococci,' as they are called, do not differ in structure from other scolices, consisting of a head, provided with four suckers and a circlet of recurved hooklets, a vesicular body, and an intermediate contracted portion or neck. The Echinococci multiply within the hydatid cyst by gemmation, but they develop no reproductive organs. If, however, an Echinococcus should gain access to the alimentary canal of a dog, it then becomes the tape-worm peculiar to that animal—the *Tænia echinococcus*.

CHAPTER XXV.

TREMATODA AND TURBELLARIA.

ORDER TREMATODA.—This order includes a group of animals, which, like the preceding, are parasitic, and are commonly known as 'suctorial worms,' or 'Flukes.' They inhabit various situations in different animals—mostly in birds and fishes—and they are usually flattened or roundish in shape. The body is provided with one or more suctorial pores for adhesion. An intestinal canal is always present, but this is simply hollowed out of the substance of the body, and does not lie in a free space, or 'perivisceral cavity.' The intestinal canal is often much branched, and possesses but a single external opening, which serves alike as an oral and an anal aperture, and is usually placed at the bottom of an anterior suctorial disc. The sexes are united in the same individual. A 'water-vascular system' is always present, and is sometimes 'divided into two portions, one with contractile and non-ciliated walls, the other with non-contractile and ciliated walls.'—(Huxley.)

The Trematode Worms are all hermaphrodite, and they pass through a series of changes in their development somewhat analogous to those observed in the *Tæniada*. This subject, however, is still involved in great obscurity, and it is too complicated to admit of description in this place. The larvæ are often tailed, but never possess cephalic hooklets and are never 'cystic.'

From the absence of a perivisceral cavity, the *Trematoda* were placed by Cuvier into a separate division of *Entozoa*, under the name of *Vers Intestinaux parenchymateux*, along with the *Tæniada* and *Acanthocephala*, in which no alimentary canal is present. By Owen, for the same reason, they are included in a distinct class, under the name of *Sterelmintha*.

The *Distoma hepaticum* (*fig.* 40) may be taken as the type of the *Trematoda*. It is the common 'Liver-fluke' of the sheep, and inhabits the gall-bladder or biliary ducts, giving rise to the disease known as the 'rot.' In form it is ovate, and flattened on its two sides, and it presents two suctorial discs, the anterior of which is perforated by the aperture of the mouth, whilst the posterior is impervious. Between the suckers is the 'genital pore,' at which the efferent ducts of the reproductive organs open on the exterior. A branched water-vascular system is present, and opens posteriorly by a small aperture. The alimentary canal bifurcates shortly behind the mouth, the two divisions thus produced giving off numerous lateral diverticula, and terminating posteriorly in blind extremities. The nervous system consists of a ring round the gullet, giving off filaments both forwards and backwards.

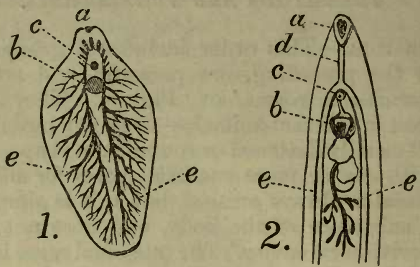


Fig. 40.—Trematoda. 1. *Distoma hepaticum*, the 'Liver-fluke,' showing the branched alimentary canal. 2. Anterior extremity of *Distoma lanceolatum*. *a*. Anterior sucker; *b*. Posterior sucker; *c*. Generative pore; *d*. Œsophagus; *e*. Alimentary canal. (After Owen.)

In *Distoma lanceolatum* (*fig*. 40, 2) the intestine has not the ramose, complex character of that of *D. hepaticum*. On the other hand, the alimentary canal, after its bifurcation, is continued on each side of the body to the posterior extremity without giving off any branches on the way, and it terminates simply in blind extremities.

Diplostomum, in its essential characters, does not differ much from *Distoma*: but it is found living gregariously in the vitreous humour and lens of the eyes of certain fresh-water fishes, such as the common Perch.

Other members of the order infest the intestines of birds and Batrachians, the gills of fishes, or the paunch of Ruminants.

Order Turbellaria.—The members of this order are almost all aquatic, and are all non-parasitic; thus differing entirely from the animals which compose the two preceding orders. Their external surface is always and permanently ciliated, and they never possess either suctorial discs, or a circlet of cephalic hooklets. A 'water-vascular system' is always present, opening externally by one or many apertures, or appearing to be entirely closed in the adult (*Nemertidæ*). As in the *Trematoda*, the alimentary canal is imbedded in the parenchyma of the body, and there is no 'perivisceral cavity.' The intestine is either straight or branched, and a distinct anal aperture may, or may not, be present.

The *Turbellaria* are divided into two sections, termed respectively the *Planarida* and the *Nemertida*.

Sub-order I. Planarida.—The Planarians (*fig*. 41) are mostly ovoid or elliptical in shape, flattened, and soft-bodied. They are for the most part aquatic in their habits, occurring in fresh water, or on the sea-shore, but occasionally found in moist earth. The integument is abundantly provided with

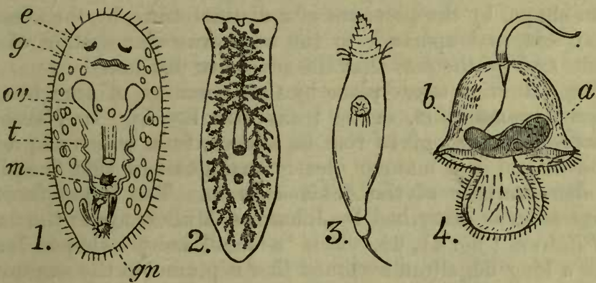


Fig. 41.—Morphology of Turbellaria. 1. *Planaria torva* (Müller). *m.* Mouth; *g.* Nerve-ganglion; *e.* Eyes; *ov.* Ovary; *t.* Testis; *gn.* Genital opening; 2. *Planaria lactea*, showing the branched (Dendrocœl) intestine. 3. Microscopic larva of *Alaurina*, a marine Turbellarian. 4. *Pilidium*, the 'pseudembryo' of a Nemertid. *a.* The alimentary canal; *b.* Rudiment of the Nemertid.

vibratile cilia, which subserve locomotion, and it also contains numerous cells which have been compared to the 'cnidæ,' or nettle-cells, of the *Cœlenterata.* There is always a considerable portion of the body situated in front of the mouth, constituting the so-called 'præ-oral region,' or 'prostomium;' and this is often modified into a singular protrusible and retractile organ, called the 'proboscis,' the exact use of which is not known. The mouth opens into a muscular pharynx, which is often evertible; and the intestine may be either straight or branched, but always terminates cæcally behind, and is never provided with an anal aperture. The 'water-vascular system' communicates with the exterior by two or more contractile apertures. The nervous system consists of two ganglia, situated in front of the mouth, united by a commissure, and giving off filaments in various directions. Pigment-spots, or rudimentary eyes, from two to sixteen in number, are often present, and are always placed in the præ-oral region of the body. The male and female organs are united in the same individual, and the process of reproduction may be either sexual, by means of true ova, or non-sexual, by internal gemmation or transverse fission.

The *Planarians* have been divided into two sections, as follows:—

Section A. Rhabdocœla.—Intestine straight, not branched. Body elongated, rounded, or oval.

Section B. DENDROCŒLA.—Intestine branched or arborescent. Body flat and broad.

SUB-ORDER II. NEMERTIDA.—The *Nemertidæ*, or 'Ribbon-worms,' agree in most essential respects with the *Planarida*. They are distinguished, however, by their elongated, vermiform shape, by the presence of a distinct anus, by the absence of an external aperture to the water-vascular system of the adult, and by the fact that the sexes are distinct.

Reproduction takes place by the formation of true ova, by internal gemmation, or by transverse fission. In *Nemertes*, however, the egg gives rise to a larva, from which the adult is developed in a manner closely analogous to that described as characteristic of the *Echinodermata*. The larval form of *Nemertes* was described by Johannes Müller, under the name of *Pilidium* (*fig.* 41, 4). It is 'a small helmet-shaped larva, with a long flagellum attached like a plume to the summit of the helmet, the edges and side-lobes of which are richly ciliated. A simple alimentary canal opens upon the under surface of the body between the lobes. In this condition the larva swims about freely; but, after a while, a mass of formative matter appears on one side of the alimentary canal, and, elongating gradually, takes on a worm-like figure. Eventually it grows round the alimentary canal, and, appropriating it, detaches itself from the *Pilidium* as a Nemertid—provided with the characteristic proboscis, and the other organs of that group of *Turbellaria*.'—(Huxley.)

CHAPTER XXVI.

NEMATELMIA.

1. ACANTHOCEPHALA. 2. GORDIACEA. 3. NEMATODA.

DIVISION II. NEMATELMIA.—This section may be considered as comprising those Scolecids in which the body has an elongated and cylindrical shape. Strictly speaking, it should include the *Nemertidæ*, but the division is not founded upon anatomical characters, and is employed here simply for convenience. Most of the *Nematelmia* possess an annulated integument; but there is no true segmentation, nor are there any locomotive appendages attached to the body. The majority are unisexual, and parasitic during the whole or a part of their existence. Three orders are comprised in this division, viz. the *Acanthocephala*, the *Gordiacea*, and the *Nematoda*.

ORDER I. ACANTHOCEPHALA.—The *Acanthocephala* are entirely parasitic, vermiform in shape, and devoid of any mouth or alimentary canal. They are provided with a kind of snout or proboscis armed with recurved hooks, which is continued backwards into a bandlike structure (*ligamentum suspensorium*), to which the reproductive organs are attached. 'Immediately beneath the integument lies a series of reticulated canals containing a clear fluid, and it is difficult to see with what these can correspond if not with some modification of the water-vascular system.'—(Huxley.) At the base of the proboscis is placed a single nervous ganglion, which gives off radiating filaments in all directions.

Besides the presence of a water-vascular system and the absence of any alimentary canal, another point of affinity between the *Acanthocephala* and the *Tæniada* has recently been established by the discovery that the adult worm is developed within a hooked embryo, from which it is secondarily produced.

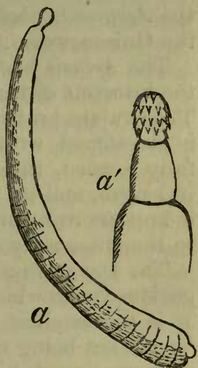


Fig. 42.—Acanthocephala. *a. Echinorhynchus gigas*, nat. size. *a'*. The head of the same magnified.

The 'Thorn-headed worms' include some of the most formidable parasites with which we are acquainted. The *Echinorhynchus* (*fig.* 42) is found in the intestinal canal of many vertebrate animals, especially of birds and fishes.

ORDER II. GORDIACEA.—The *Gordiacea*, or 'Hair-worms,' are thread-like parasites which in the earlier stages of their existence inhabit the bodies of various insects, chiefly of beetles and grasshoppers. They possess a mouth and alimentary canal, but they are not provided with a distinct anal aperture. The sexes are distinct, and they leave the bodies of the insects which they infest, in order to breed; subsequently depositing their ova in long chains, either in water or in some moist situation.

In form the *Gordiacea* are singularly like hairs, and they often attain a length many times greater than that of the insect which harbours them.

ORDER III. NEMATODA (or *Nematoidea*).—The *Nematoda*—'Thread-worms' or 'Round-worms'—are of an elongated and cylindrical shape; and are often, though by no means always, parasitic in the interior of other animals. They possess a distinct mouth and an alimentary canal which is freely suspended in an abdominal cavity, and terminates posteriorly in a distinct anus. They also possess a system of canals, in some cases contractile, which open externally near the anterior part of the body, and are probably homologous with the water-vascular system of the *Tæniada* and *Trematoda*.—(Huxley.) The sexes are distinct, and the males are usually less frequently met with, and of smaller size than the females. The nervous system is mostly well developed, and is in the form of a ganglionic ring, surrounding the œsophagus, and sending filaments backwards.

As before said, most of the *Nematoda* are internal parasites, inhabiting the alimentary canal, the pulmonary tubes, or the areolar tissue, in man and in many other vertebrate animals; but a large section of the order are of a permanently free habit of existence.

The most familiar examples of the parasitic *Nematoda* are the *Ascaris lumbricoides*, the little *Oxyuris*, the *Trichina*, and the Guinea-worm.

The *Ascaris lumbricoides*, or common Round-worm, inhabits the intestine of man, often attaining a length of several inches. The ova are probably expelled with the fæces, and the embryo is developed within the ovum prior to its rupture. When fully formed, the embryo is about one hundredth of an inch in length, and its development is not exactly known, though it appears to be directly transferred from river- or pond-water to the alimentary canal of some vertebrate animal.

The *Oxyuris vermicularis*, or 'Small Thread-worm,' is a gregarious worm which inhabits the rectum, especially of children. It is the smallest of the intestinal worms of man, its average length not being more than a quarter of an inch, but the females are much bigger than the males.

The *Trichina spiralis* is a singular Nematoid, which gives rise to a painful and very generally fatal train of symptoms, somewhat resembling rheumatic fever, and known as Trichiniasis. The *Trichina* is known in two different conditions, sexually immature or mature. In its sexually immature condition it inhabits the muscles, usually of the pig, in vast numbers, each worm being coiled up in a little capsule or cyst. In this condition the worm is incapable of further development, and may remain, apparently for an indefinite period, without change, and without seeming to produce any injurious results to the animal affected. If, however, a portion of trichinatous muscle be eaten by a warm-blooded vertebrate, and so introduced into the alimentary canal, an immediate development of young *Trichinæ* is the result. The immature worms escape from their enveloping cysts, grow larger, develop sexual organs, and give birth to a numerous progeny, which they produce viviparously. The young *Trichinæ* thus produced perforate the walls of the alimentary canal, and, after working their way amongst the muscles, become encysted. If the animal in which these changes go on has sufficient vitality to bear up under the severe symptoms which are produced by the migration of the *Trichinæ*, he is now safe; since they can not become sexually mature, or develop themselves further, until again transferred to the alimentary canal of some other animal.

The Guinea-worm (*Dracunculus* or *Filaria medinensis*) is a Nematode worm, which inhabits, during one stage of its existence, the cellular tissue of the human body, generally attacking the legs, and often attaining a length of several feet. All known specimens of this parasite are impregnated females, containing a large number of young. The worm remains imbedded in the body, in a more or less quiescent condition, for a year or more, at the end of which time it seeks the surface, in order to get rid of its young. No external aperture to the genital organs has hitherto been proved to exist, and it seems possible that the young are produced within the body of the parent by a process of internal gemmation. The young *Filaria* consists of a vermiform body, terminating in a hair-like tail, and when set free from the parent, its further development probably takes place in water, when it is believed to be converted into one of the 'Tank-worms,' so common in India. In this condition it is possible, as some believe, that sexual organs are developed, and that the females are impregnated. The worm is believed to gain access to the body of bathers, when still extremely minute. According to Dr. Bastian, however, it appears probable that the Guinea-worm 'is a parasite only accidentally, and that it and its parents were originally free Nematoids.'

The second section of the *Nematoda* comprises worms, which are not at any time parasitic, but which are permanently free. These 'free Nematoids' constitute the family of the *Anguillulidæ*, of which about two hundred species have been already described, mostly inhabiting fresh water or the shores of the sea. They resemble the parasitic Nematoids in all the essential features of their anatomy, but they differ in often possessing pigment-spots, or rudimentary eyes, in being mostly provided with a terminal sucker, and in bringing forth comparatively few ova at a time; the dangers to which the young are exposed being much less than in the parasitic forms. Amongst the more familiar Nematoids are the Vinegar Eel (*Anguillula aceti*) and the *Tylenchus* (or *Vibrio*) *tritici*, which produces a sort of excrescence or gall upon the ear of wheat, causing the disease known to farmers as the 'Purples,' or 'Ear Cockle.'

The parasitic and free Nematoids are connected together by an *Ascaris* (*A. nigrovenosa*), which in succeeding generations is alternately free and parasitic. This *Ascaris* has long been known as inhabiting the lungs of the frog, but it has been shown that 'the young of this animal become real, free Nematoids; for, after passing from the intestine of the frog into damp earth or mud, they grow rapidly, and actually develop in the course of a few days, whilst still in this external medium, into sexually mature animals. Young, differing somewhat in external characters from their parents, are soon produced by them, and these attain merely a certain stage of development whilst in the moist earth, arriving at sexual maturity only after they have become parasites, and are ensconced in the lung of the frog.'—(Bastian.) This extraordinary history is rendered still more remarkable, if it should be proved that the young of the parasitic forms of this *Ascaris* are produced by a process of parthenogenesis; and this seems to be highly probable, since none of the individuals which are found as parasites are males, but are universally females.

CHAPTER XXVII.

ROTIFERA.

SUB-CLASS ROTIFERA (*Rotatoria*).—The *Rotifera*, or 'Wheel-animalcules,' constitute a very natural group, the exact position of which has been a good deal disputed, and is still doubtful. They are looked upon here as a distinct division of the *Scolecida*, following Huxley; but they are very frequently placed with the *Annelida* amongst the lower division of the *Annulosa* (*Anarthropoda*).

The *Rotifera* are *Annuloida of a minute size, never parasitic, inhabiting water, and usually provided with an anterior ciliated disc, capable of inversion and eversion. In the females there is a distinct mouth, intestinal canal, and anus. A nervous system is also present, consisting of ganglia, situated near the anterior extremity of the body, and sending filaments backwards. A water-vascular system is also present.*

Most of the *Rotifera* are entirely invisible to the naked eye, and they are all extremely minute. Nevertheless, as remarked by Mr. Gosse, 'so elegant are their outlines, so brillantly translucent their texture, so complex and yet so patent their organisation, so curious their locomotive wheels, so unique their apparatus for mastication, so graceful, so vigorous, so fleet, and so marked with apparent intelligence their movements, so various their forms and types of structure,' that they form one of the most interesting departments of zoological and microscopical study. They are all aquatic in their habits, and in the great majority of cases are free-swimming animals, some, however, being permanently fixed, as is the case with *Stephanoceros* (*fig.* 43) and *Floscularia*. They are usually simple, but are occasionally composite, forming colonies, as in *Megalotrocha*. As a rule, the male and female *Rotifera* differ greatly from one another, the males being smaller than the females, destitute of any masticatory or digestive apparatus, and more or less closely resembling the young form of the species. The most characteristic organ in the great majority of the *Rotifera* is the so-called 'wheel-organ,' or 'trochal disc,' which is always situated at the cephalic or distal end of the body, and consists of a circlet of cilia, which, when in action, vibrate so rapidly as to produce the illusory impression that the entire disc is rotating. The disc, which carries the cilia, is capable of eversion and inversion, and may be circular, reniform, bilobed, four-lobed, or divided into several lobes. It serves the purpose of locomotion in the free-swimming forms, and in all it serves to produce currents in the water, which convey the food to the mouth.

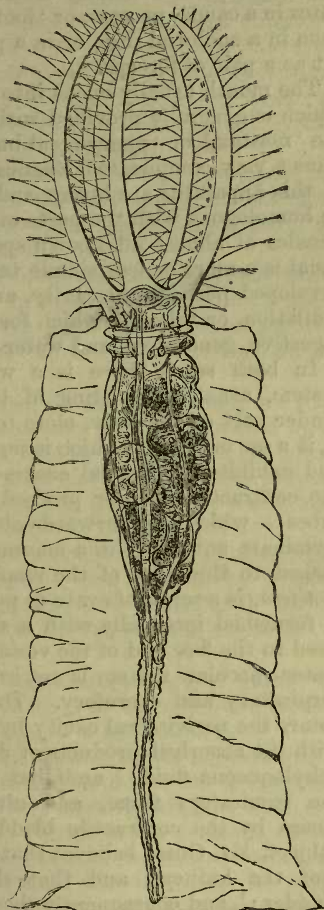


Fig. 43.—Rotifera. The Crown Animalcule (*Stephanoceros Eichornii*), a fixed Rotifer; greatly enlarged.

In *Chætonotus*, and one or two other forms, there is no true wheel-organ, capable of protrusion and retraction, but the cilia are variously disposed over the surface of the body.

The proximal extremity of the body in the free forms terminates in a caudal process, or 'foot,' sometimes telescopic, which ends in a suctorial disc, or in a pair of diverging 'toes,' which act as a pair of forceps.

The mouth usually opens into a pharynx, or 'buccal funnel,' which is generally provided with a muscular coat, constituting the 'mastax,' or 'pharyngeal bulb,' and which generally contains a very complicated masticatory apparatus.* The parts of this apparatus are horny, and are believed by Mr. Gosse to be homologous with the parts of the mouth in Insects. In the females of almost all known species of *Rotifera* the intestinal canal is a more or less simple tube, extending through a well developed perivisceral cavity, and terminating posteriorly in a dilation, or 'cloaca,' which forms the common outlet for the digestive, generative, and water-vascular systems.

In both sexes there is a well developed water-vascular system, usually consisting of the following parts:—In the hinder part of the body, close to the cloaca, and opening into it, is a sac or vesicle, which is termed the 'contractile bladder,' and exhibits rhythmical contractions and dilatations. From the contractile bladder proceed two tubes—the 'respiratory tubes'—which pass forwards along the sides of the body, and terminate anteriorly in a manner not quite ascertained. Attached to the sides of the respiratory tubes, in all the larger *Rotifera*, is a series of ovate or pyriform vesicles, each of which is furnished internally with a single central cilium, which is fixed to the free end of the vesicle. The exact function of this water-vascular system is not known, but it is most probably respiratory and excretory. Dr. Leydig believes that water enters the perivisceral cavity by endosmose, where it mingles with the absorbed products of digestion, to form the so-called 'chylaqueous fluid;' and that the effete fluid is excreted by the respiratory tubes, and ultimately discharged into the cloaca by the contractile bladder. Taking this view of the subject, Mr. Gosse believes that 'the respiratory tubes represent the kidneys, and that the bladder is a true urinary bladder;' and consequently that 'the respiratory and urinary functions are in the closest relation with one another.' This observer, further, finds a decided analogy between the above

* The lower jaws, or 'incus,' consist of a fixed portion, the 'fulcrum,' to which are attached two movable blades—the 'rami.' The upper jaws, or 'mallei,' consist each of a handle, or 'manubrium,' to which is hinged a toothed blade, or 'uncus.'

system in the *Rotifera*, and the long and tortuous renal tubes of the *Insecta*, to which class he believes the *Rotifera* to be most nearly allied.

The nervous system of the *Rotifera* constitutes a cerebral mass, 'which for its proportionate volume may compare with the brain of the highest vertebrates.' It is placed anteriorly, and usually on the dorsal aspect of the body, and the eye—in the shape of a red pigment-spot—is invariably situated like a wart upon it. Other sense-organs, probably tactile, are often present, in the form of two knobs surmounted by tufts of bristles, placed at the back of the head.

The muscular system of the *Rotifera* is well developed, consisting of bands which produce the various movements of the body and foot, whilst others act upon the various viscera, and others effect the movements of the jaws.

The typical group of the *Rotifera* is that of the *Notommatina* (*Hydatinea* of Ehrenberg). In this group the animals are all permanently free, and are never combined into colonies, while the integument is flexible, and the body is never encased in a tube.

Stephanoceros and *Floscularia*, on the other hand, are fixed, and are enclosed in a gelatinous tube which is secreted by the animal. *Melicerta* inhabits a tubular case, which the animal forms for itself by means of a special organ for the purpose; whilst *Polyarthra* and *Triarthra* are protected by a stiff shell, or 'lorica.'

In *Triarthra*, there are twelve ensiform fins, jointed to the body by distinct shelly tubercles, and moved by powerful muscles. These natatory organs are considered by Mr. Gosse to be homologous with the articulated limbs of the *Arthropoda*.

In *Asplanchna*, whilst the masticatory organs, gullet, and stomach are well developed, there is no intestine, the stomach 'hanging like a globe in the centre of the body-cavity.'

Affinities of Rotifera.—In their external appearance, the *Rotifera* approximate closely to the *Infusoria*, but the organisation of the former presents a very striking advance when compared with that of the latter. Thus, in the *Infusoria* there is no differentiated body-cavity, bounded by distinct walls, and the alimentary canal is imperfect, the digestive sac simply opening inferiorly into the diffluent sarcode of the centre of the body. Further, there are no traces of a nervous system, and the contractile vesicles, if looked upon as representing the water-vascular system, are a very rudimentary form of this apparatus. In the *Rotifera*, on the other hand, the alimentary canal forms a complete tube, having an oral and an anal aperture, and not communicating with the surrounding perivisceral cavity; and there is a well developed nervous system, and a highly complex water-vascular system. A real affinity is found to subsist, however, between the *Rotifera* and the *Planarida*; both possessing external cilia, a nervous system, and a well developed water-vascular apparatus, the characters of which are not dissimilar in the two groups. In the *Planarida*, however, the sexes are united in the same individual, and there is no anal aperture; whereas in the *Rotifera*, the sexes are distinct, and there is a distinct anus. To the true *Arthropoda*, as already pointed out, the *Rotifera* show some points of affinity, but these are hardly sufficiently numerous or decided to warrant the removal of the group from the *Annuloida* to the *Annulosa*.

ANNULOSA.

CHAPTER XXVIII.

ANNULOSA.

1. General Characters of Annulosa. 2. General Characters of Anarthropoda. 3. Class Gephyrea. 4. General Characters of the Class Annelida.

Sub-kingdom Annulosa.—The members of this sub-kingdom are distinguished by the possession of *a body which is composed of numerous segments, or 'somites,' arranged along a longitudinal axis. A nervous system is always present, and consists of a double chain of ganglia, running along the ventral surface of the body, and traversed anteriorly by the œsophagus. The limbs (when present) are turned towards the neural aspect of the body.*

The sub-kingdom *Annulosa* may be divided into two primary divisions, according as the body is provided with articulated appendages, or not; these divisions being termed respectively the *Arthropoda* and the *Anarthropoda.* The first of these comprises Crustaceans, Spiders, Scorpions, Centipedes, and Insects; whilst the latter includes the Spoon-worms, Leeches, Earth-worms, Tube-worms, and Sand-worms.

Division I. Anarthopoda.—In this division of the *Annulosa*, *the locomotive appendages are never distinctly jointed or articulated to the body.* In this division are included three classes, viz.:—the *Gephyrea*, the *Annelida*, and the *Chætognatha.*

Class I. Gephyrea (=*Sipunculoidea*).—This class includes certain worm-like animals in which the body is sometimes obviously annulated, sometimes not; but there are no ambulacral tubes nor foot-tubercles. The nervous system consists of a gangliated cord placed along the ventral surface of the body.

The *Sipunculus*, and its allies, make up this class, and from their affinity to the worm-like Holuthurians they have often been placed amongst the *Echinodermata.* They are not, however, provided with an ambulacral system, the integument is not capable of secreting calcareous matter, and there are no traces of any radiate arrangement of the nervous system.

The *Sipunculus* is a worm which is found burrowing in the sand of the coasts of most of our European seas, or which inhabits the cast-away shells of dead univalve Molluscs. The different species differ much in length, varying from half an inch to a foot or more. The body is cylindrical, covered by a delicate cuticle, beneath which is a thick, muscular, and highly contractile coat. The anterior portion of the body forms a retractile trunk or proboscis, at the extremity of which is the mouth surrounded by a circlet of simple tentacles. The alimentary canal is proportionately of great length, and is much convoluted. Upon reaching the posterior extremity of the body it is reflected forwards, and it terminates in a distinct anus which is placed anteriorly near the junction of the body with the proboscis.

In *Echiurus*, which is found on the coasts of the North Sea, the body is provided posteriorly with zones of horny bristles; and in the *Sternaspis* of the Adriatic similar zones of bristles are found anteriorly as well as posteriorly.

The British species of the class are grouped by Professor E. Forbes as follows:—

Fam. I. *Sipunculacea*, having a retractile proboscis, at the base of which the anus is placed, and round the extremity of which is seen a circlet of tentacles.

Fam. II. *Priapulacea*, having a retractile proboscis but no tentacula, and having the anus placed at the extremity of a long, filiform, caudal appendage.

Fam. III. *Thalassemacea*, having a proboscis to which a long fleshy appendage is attached. There are no oral tentacula, and the anus is placed at the posterior extremity of the body.

CLASS II. ANNELIDA (= *Annulata*).—The *Annelida* are distinguished from the preceding by the possession of distinct external segmentation; the nervous system is composed of a ventral, double, gangliated cord.

This class comprises elongated, worm-like animals, in which the integument is always soft, and the body is more or less distinctly segmented, each segment usually corresponding with a single pair of ganglia in the ventral cord. Each segment may also be provided with a pair of lateral appendages, but these are never articulated to the body, and are never so modified in the region of the head, as to be converted into masticatory organs.

In the higher *Annelida* each segment consists of two arches, termed, from their position, respectively the 'dorsal arc,' and the 'ventral arc;' and each bears two lateral processes, or 'foot-tubercles' (*parapodia*), one on each side. Each 'foot-tubercle' is double, being composed of an upper process, called the 'notopodium,' or 'dorsal oar,' and a lower process, termed the 'neuropodium,' or 'ventral oar.' The foot-tubercles, likewise, support bristles, or 'setæ,' and a soft, cylindrical appendage, which is termed the 'cirrhus' (*fig.* 44).

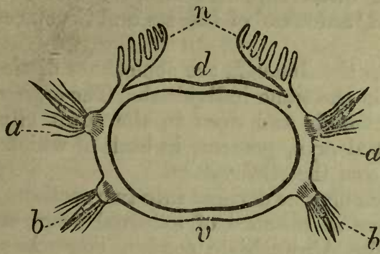


Fig. 44.—Diagrammatic transverse section of an Annelide. *d*. Dorsal arc; *v*. Ventral arc; *n*. Branchiæ; *a*. Notopodium or dorsal oar; *b*. Neuropodium or ventral oar, both carrying setæ and a jointed cirrhus.

The number of the segments varies much, being as many as 400 in *Eunice gigantea*; and, generally, there is not a distinct head which is separable from the succeeding rings of the body. When such a distinct head appears to be present, it is not comparable with the head of the *Arthropoda*, but is really a greatly modified præoral region, or 'prostomium,' as is shown by the position of the mouth.

The digestive system of the Annelides consists of a mouth, sometimes armed with horny jaws, a gullet, stomach, intestine, and a distinct anus.

As regards the vascular system, 'no Annelide ever possesses a heart comparable to the heart of a Crustacean or Insect; but a system of vessels, with more or less extensively contractile walls, containing a clear fluid, usually red or green in colour, and, in some cases only, corpusculated, is very generally developed, and sends prolongations into the respiratory organs, when such exist.'—(Huxley.) This system has been termed the 'pseudo-hæmal system,' and its vessels are considered by Professor Huxley as being 'extreme modifications of organs homologous with the water-vessels of the *Scolecida*;' since the perivisceral cavity, with its contained corpusculated fluid (chylaqueous fluid), is believed by M. de Quatrefages to be the true homologue of the vascular system of Crustacea and Insects.

Respiration is effected by the general surface of the body, by saccular involutions of the integument, or by distinct external gills, or branchiæ.

The nervous system consists of a double, ventral, gangliated cord, which is traversed anteriorly by the œsophagus; the 'præ-œsophageal,' or 'cerebral,' ganglia being connected by lateral cords or commissures with the 'post-œsophageal' ganglia. Pigment-spots, or 'ocelli,' are present in many; and the head often supports two, or more, feelers, which differ from the 'antennæ' of Insects and Crustacea, in not being jointed.

The sexes in the *Annelida* are sometimes distinct, and sometimes united in the same individual. The embryos are almost universally ciliated, and even in the adult cilia are almost always, if not always, present, in both of which respects this class differs from the *Arthropoda*.

The *Annelida* may be divided into two sections, characterised by the presence or absence of external respiratory organs or branchiæ. The Abranchiate section comprises the Leeches and the Earth-worms; whilst the Branchiate division includes the Tube-worms (*Tubicola*) and the Sand-worms (*Errantia*).

CHAPTER XXIX.

ORDERS OF ANNELIDA.

ORDER I. HIRUDINEA (*Discophora*, or *Suctoria*).—This order includes the Leeches, and is characterised by the possession of a locomotive and adhesive sucker, posteriorly, or at both extremities, and by the absence of bristles and foot-tubercles. The sexes are united in the same individual, and the young do not pass through any metamorphosis.

Fig. 45.—Medicinal Leech (*Sanguisuga officinalis*).

The Leeches are aquatic, vermiform animals, mostly inhabiting fresh water, though a few species are marine. Locomotion is effected either by swimming by means of a serpentine bending of the body, or by means of one or two suctorial discs. In those forms in which there is only a single sucker (posterior), the head or anterior extremity of the body can be converted into a suctorial disc. The body is ringed, as many as one hundred annulations being present in the common Leech; but it is not divided into distinct somites, and there are no lateral appendages of any kind. The mouth is sometimes edentulous, but is usually armed with teeth. The alimentary canal is short, and is united to the skin by means of a spongy vascular tissue. The pseudo-hæmal system consists principally of four great longitudinal trunks, connected by lateral vessels, and devoid of any special dilatations. Respiration appears to be effected by means of a number of pulmonary sacs, which are formed simply by an involution of the integument, and which open externally by minute apertures, termed 'stigmata.' In the common Leech there are about seventeen of these vesicles on each side of the body, their openings being placed on the abdominal surface. These saccular involutions of the integument certainly secrete the mucus with which the body of the animal is lubricated, and it is believed by some that their function is solely excretory, and that they answer to the kidneys of higher animals. In this case respiration must be effected by the general surface of the body; but there is no reason why the same organs should not perform both functions, since a close relationship subsists between the two.

The nervous system consists of a præ-œsophageal ganglion, which gives branches to a number of simple eyes, or ocelli, which are placed on the head, and which is united by lateral œsophageal cords to the ventral gangliated chain.

The sexes are united in the same individual, but the Leeches are nevertheless incapable of self-fertilisation.

The common Horse-leech is not provided with any dental apparatus; but the Medicinal Leech (*Sanguisuga officinalis*) (*fig.* 45) has its mouth furnished with three crescentic jaws, the convex surfaces of which are serrated with minute teeth. This species is chiefly imported from Hungary, Bohemia, and Russia.

ORDER II. OLIGOCHÆTA (*Terricola*).—The members of this order, comprising the Earth-worms (*Lumbricidæ*), and the Water-worms (*Naïdidæ*), are distinguished by the fact that their locomotive appendages are in the form of chitinous setæ or bristles, attached in rows to the sides and ventral surface of the body. They are all hermaphrodite.

In the common Earth-worm (*Lumbricus*) the body is cylindrical, attenuated at both extremities, and carrying in the adult a thickened zone, which occupies from six to nine rings in the anterior part of the body, is connected with reproduction, and is termed the 'clitellum,' or 'saddle.' Locomotion is effected by eight rows of short bristles or setæ, four of which are placed laterally and four on the ventral surface of the body; these representing the foot-tubercles of the higher Annelides. The mouth is edentulous, and opens into a short œsophagus, which leads to a muscular crop, or 'pro-ventriculus,' succeeded by a second muscular dilatation, or gizzard. The intestine is continued straight to the anus, and is constricted in its course by numerous transverse septa, springing from the walls of the perivisceral cavity. The pseudo-hæmal system is well developed; and there exists, in even greater numbers, the same series of lateral sacculi which we have seen in the Leeches, and which have either a respiratory or a renal function.

Of the little *Naïdidæ*, the most familiar is the *Tubifex rivulorum*, which is of common occurrence in the mud of ponds and streams. It is from half an inch to one inch and a half in length, and of a bright red colour. The pseudo-hæmal system is provided with two contractile cavities or hearts; and there is present the same system of lateral tubes, opening externally by pores, as occurs in the Earth-worms.

The *Naïdidæ* are chiefly noticeable on account of the singular process of non-sexual reproduction which they present, before they attain sexual maturity. In this process the *Naïs* throws out a bud between two rings, at a point generally near the middle of the body. Not only is this bud developed into a fresh individual, but the two portions of the parent marked out by the budding point likewise became developed into separate individuals. The portion of the parent in front of the bud develops a tail, whilst the portion behind the bud develops a head. Prior to the detachment of the bud, other secondary buds are formed from the same segment, each in front of the one already produced; and in this way, before separation takes place, a chain of organically connected individuals is produced, all of which are nourished by the anterior portion of the primitive worm.

ORDER III. TUBICOLA (*Cephalobranchiata*).—The Annelides which are included in this order inhabit tubes, which may be calcareous, and secreted by the animal itself, or may be composed of grains of sand or pieces of broken shell, cemented together by a glutinous secretion from the body. The body-rings are mostly provided with fasciculi of bristles set upon lateral foot-tubercles or parapodia, by means of which the animal is enabled to draw itself in and out of its tube. The alimentary canal is loosely attached to the integument. The *Tubicola* are unisexual, and the young pass through a metamorphosis.

When the tube of a Tubicolar Annelide is a true calcareous secretion from the body of the animal, it is, nevertheless, readily distinguished from the shell of the Mollusca, by the fact that there is no organic connection of any kind between the animal and its tube.

The pseudo-hæmal system has its usual arrangement, and the contained fluid is usually red in colour, but is olive-green in *Sabella*. The respiratory organs are in the form of filamentous branchiæ, attached to, or near, the head, generally in two lateral tufts, arranged in a funnel-shaped or spiral form. Each filament is fringed with vibrating cilia, and the tufts are richly supplied with fluid from the pseudo-hæmal system. There is no special apparatus required to drive the blood back to the heart, but this is effected by the contractile power of the gills themselves. From the position of the branchiæ upon, or near, the head, the *Tubicola* are often known as the 'cephalo-branchiate' Annelides (*fig.* 46).

Reproduction in the *Tubicola* is generally sexual, the sexes being in different individuals; but spontaneous fission has also been observed. As regards their development, the process has been thus described, as it occurs in *Terebella* :—The embryo, which is at first a free-swimming, ciliated body, 'lengthens, and the cilia, which were at first generally diffused, become confined to a cincture behind the head, a transverse ventral band near the tail, and a small circle round that part. The head is distinguished by two red eye-specks; new segments are successively added, one behind the other, and always in front of the anal one; but as yet the embryo is apodal. The tubercles and setæ are next developed in the same order, and a free-swimming, or "errant" Annelide ensues. Finally the cilia of the buccal rings are lost, the young *Terebella* reposes, and envelops itself in a mucous tube.'—(Owen.) As the young tubicolar Annelide is thus free, or 'errant,' before it becomes finally enveloped in a tube, it is generally believed that the *Tubicola* should be looked upon as really higher than the next order of *Annelida*, viz. the *Errantia*. It appears, however, more probable that the stationary condition of the adult *Tubicola* should rather be regarded as an instance of 'retrograde development.'

The most familiar of the Tubicola is the *Serpula*, the contorted and winding calcareous tubes of which must be known to almost every one, as occurring on shells or stones on the sea-shore. One of the cephalic cirrhi in *Serpula* is much developed, and carries at its extremity a conical plug, or operculum, whereby the mouth of the tube is closed, when the animal is retracted within it.

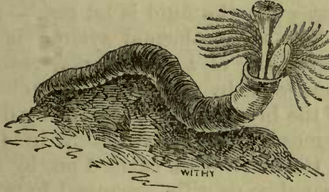


Fig. 46.—*Serpula*.

Equally familiar with *Serpula* is *Terebella*, the animal of which is included in a tube composed of sand and fragments of shell, cemented together by a glutinous secretion.

ORDER IV. ERRANTIA (*Nereidea*).—This order comprises *free* Annelides, which possess setigerous foot-tubercles. The respiratory organs are generally in the form of tufts of external branchiæ, arranged along the back or the sides of the body. They are unisexual, and the young pass through a metamorphosis. This order includes most of the animals which are commonly known as Sand-worms and Sea-worms, together with the familiar Sea-mice.

The integument is soft, and the body is very distinctly divided into a great number of rings or segments, each of which, in the typical forms, possesses the following structure. The segment consists of two arches, a lower or 'ventral arc,' and an upper or 'dorsal arc,' with a 'foot-tubercle' on each side. Each foot-tubercle consists of an upper process, or 'notopodium,' and a lower process, or 'neuropodium,' each of which carries a tuft of bristles, or 'setæ,' and a species of tentacle termed the 'cirrhus' (*fig.* 44).

The anterior extremity of the body is usually so modified as to be distinctly recognisable as the head, and is provided with eyes, and with two or more feelers, which are not jointed, and are, therefore, not comparable with the antennæ of Crustacea and Insects. The mouth is placed on the inferior surface of the head, and is often furnished with one or more pairs of horny jaws, working laterally. The pharynx is muscular, and forms a sort of proboscis, being provided with special muscles, by means of which it can be everted and again retracted. In most there is no distinction between stomach and intestine, and the epithelium of the alimentary canal, like that of the preceding orders, is ciliated. The perivisceral cavity is filled with a colourless corpusculated fluid—the 'chyl-aqueous fluid,'—which 'performs one of the functions of an internal skeleton, acting as the fulcrum or base of resistance to the cutaneous muscles, the power of voluntary motion being lost when the fluid is let out.'—(Owen.)

The pseudo-hæmal system is well developed, and consists essentially of a long dorsal vessel, and a similar ventral one, connected by transverse branches, and furnished at the bases of the branchiæ with pulsating dilatations. The contained fluid is mostly red, but is yellow in *Aphrodite* and *Polynoe*.

Respiration is carried on by means of a series of external branchiæ or gills, arranged in tufts upon the sides of the body on its dorsal aspect, along the middle of the body only, or along its entire length. From the position of the branchiæ, the members of this order are often spoken of as the 'Dorsibranchiate' (or more properly 'Notobranchiate') Annelides.

In the Sea-mouse (*Aphrodite*), the back is covered with a double row of imbricated plates, which are called 'elytra,' or 'squamæ,' and respiration is effected by the periodical elevation and depression of these plates, whereby water is alternately admitted into, and expelled from, a space beneath them.

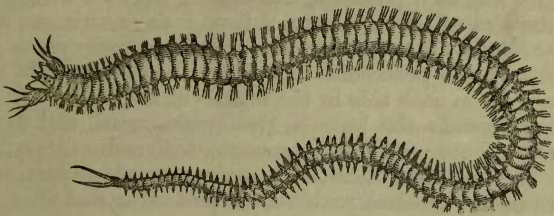


Fig. 47.—'Errant' Annelide. *Nereis*, showing the 'head' with its appendages, and the setigerous parapodia.

This space is separated by a membrane from the perivisceral cavity below.

The nervous system in the *Errantia* has its typical form, consisting of a double gangliated ventral cord, two ganglia of which are appropriated to each segment. The præ-œsophageal, or cerebral, ganglia are of large size, and send filaments to the ocelli and feelers.

The sexes in the *Errantia* are in different individuals, and reproduction is usually sexual, though in some cases gemmation is known to occur. The process of gemmation is carried on by a single segment, and so long as it continues, the budding individual remains sexually immature; though the young thus produced develop generative organs. Thus, there is in these cases a kind of alternation of generations, or rather an alternation of generation and gemmation; the oviparous individuals producing eggs from which the gemmiparous individuals are born; these, in their turn, but by a non-sexual process, producing the oviparous individuals.

The embryo usually appears, on its liberation from the ovum, as a free-swimming, ciliated body, possessing a mouth, intestine, and anus. The cilia are primarily diffused, but become aggregated so as to form a single median belt, or two bands, one about each extremity. The head, with its feelers and eyespecks, appears at one extremity, whilst the segments of the body begin to be formed at the other. Each segment is developed in four parts, the two principal ones forming half-rings, united by shorter side-pieces, from which the setigerous foot-tubercles are developed. The ciliated band or bands finally disappear, and new rings are rapidly added by intercalation between the head and the segments already formed.

Amongst the best known of the *Errantia* is the common Lob-worm of our coasts (*Arenicola piscatorum*), which is used by fishermen for bait. The Lob-worm lives in deep canals which it hollows out in the sand of the sea-shore, literally eating its way as it proceeds, and passing the sand through the alimentary canal, so as to extract from it any nutriment which it may contain. It possesses a large head, without eyes or jaws, and with a short proboscis. There are thirteen pairs of branchiæ, placed on each side in the middle of the body.

In the *Nereidæ* the body is greatly elongated, and consists of a great number of similar segments, with rudimentary branchiæ. The head is distinct, and carries eyes and feelers, whilst the mouth is furnished with a large proboscis, and often with two horny jaws (*fig.* 47). In the *Eunicea* the branchiæ are usually well developed and of large size, and the mouth is armed with seven, eight, or nine horny jaws. *Eunice gigantea* attains sometimes a length of over four feet, and may consist of more than four hundred rings.

Distribution of Annelida in Time.—Of the *Annelida* the only orders which are known to have left any traces of their existence in past time are the *Tubicola* and the *Errantia*; of which the former are known by their investing tubes, whilst the latter are only recognised by the tracks which they left upon ancient sea-bottoms, or by their burrows in sand or mud. These tracks and burrows of Annelides are found commonly in rocks of almost all ages from the Cambrian period upwards. Those tracks which have been caused simply by the passage of the worm over the surface of the mud are termed by Mr. Salter *Helminthites*, whilst the burrows are called *Scolites* (or *Scolithus*).

Tubicolar Annelides are known to occur from the Silurian Rocks upwards. The well known Silurian fossil, *Tentaculites*, is generally believed to belong to this order, but it is referred by M. Barrande to the *Pteropoda* (*Mollusca*). *Cornulites*, and *Trachyderma*, however, are undoubted Silurian *Tubicola*. The *Microconchus carbonarius* is a little spiral Tubicolar Annelide, nearly allied to the *Spirorbis* of our seas, which is not uncommonly found in strata belonging to the Carboniferous period; and the genus *Spirorbis* itself is represented even in the Silurian period.

TABULAR VIEW OF THE ANNELIDA.

Division A. Abranchiata.—No external organs of respiration.

Order I. *Hirudinea.*—No bristles or foot-tubercles: locomotion by means of a suctorial disc at one or both extremities. Ill. Gen. *Hirudo, Clepsine, Pontobdella.*

Order II. *Oligochæta.*—Locomotion by means of rows of stiff bristles, or 'setæ;' no foot-tubercles. Ill. Gen. *Lumbricus, Naïs, Tubifex.*

Division B. BRANCHIATA.—Respiratory organs in the form of external branchiæ.

Order III. *Tubicola.*—Body protected by a calcareous or arenaceous tube. Branchiæ attached to, or near, the head (*Cephalobranchiata*). Ill. Gen. *Serpula*, *Terebella*, *Sabella*.

Order IV. *Errantia.*—Animal free, with setigerous foot-tubercles. Branchiæ in tufts, attached to the sides of the body, in the middle of dorsal region only, or along its entire length (*Dorsibranchiata*). Ill. Gen. *Arenicola* (Lob-worm), *Nereis* (Sea-centipede), *Aphrodite* (Sea-mouse).

CLASS III. CHÆTOGNATHA (Huxley).—The remaining class of the *Anarthropoda* has been recently constituted by Professor Huxley under the name of *Chœtognatha*, for the reception of the single genus *Sagitta*, which had been formerly placed amongst the *Annelida*.

The *Sagittœ* are singular marine animals, transparent, and elongated in form, and usually not more than an inch in length. The following are the characters ascribed to the class by Huxley:—

'The head is provided with several, usually six, sets of strong, bilaterally symmetrical oral setæ, two of which, long and claw-like, lie at the sides of the mouth; while the other four sets are short and lie on that part of the snout which is produced in front of the oral aperture. The posterior part of the body is fringed on each side by a delicate striated fin-like membrane, which seems to be an expansion of the cuticle. In some species the body is beset with fine setæ. The intestine is a simple, straight tube, extending from the mouth to the anus; the latter opens on the ventral surface, just in front of the hinder extremity. A single oval ganglion lies in the abdomen, and sends, forwards and backwards, two pairs of lateral cords. The lateral cords unite in front of and above the mouth into a hexagonal ganglion. This gives off two branches which dilate at their extremities into the spheroidal ganglia, on which the darkly pigmented imperfect eyes rest. The ovaries, saccular organs, lie on each side of the intestine and open on either side of the vent; *receptacula seminis* are present. Behind the anus, the cavity of the tapering caudal part of the body is partitioned into two compartments; on the lateral parietes of these, cellular masses are developed which become detached, and floating freely in the compartment, develop into spermatozoa. These escape by spout-like lateral ducts, the dilated bases of which perform the part of *vesiculœ seminales*. The embryos are not ciliated, and undergo no metamorphosis.'—(See *Introduction to the Classification of Animals*, p. 52.)

CHAPTER XXX.

ARTHROPODA.

DIVISION II. ARTHROPODA, OR ARTICULATA.—The remaining members of the sub-kingdom *Annulosa* are distinguished by the possession of *jointed appendages, articulated to the body*; and they form the second primary division—often called by the name *Articulata*. As this name, however, has been employed in a wider sense than is understood by it here, it is, perhaps, best to adopt the more modern term *Arthropoda*.

The members of this division, comprising the *Crustacea* (Lobsters, Crabs, &c.), the *Arachnida* (Spiders and Scorpions) the *Myriapoda* (Centipedes), and the *Insecta*, are distinguished as follows:—

The body is composed of a series of segments, arranged along a longitudinal axis; each segment, or 'somite,' occasionally, and some always, being provided with articulated appendages. Both the segmented body and the articulated limbs are more or less completely protected by a chitinous exoskeleton, formed by a hardening of the cuticle. The nervous system in all, at any rate in the embryonic condition, consists of a double chain of ganglia, placed along the ventral surface of the body, united by longitudinal commissures, and traversed anteriorly by the œsophagus. The hæmal system, when differentiated, is placed dorsally, and consists of a contractile cavity, or heart, provided with valvular apertures, and communicating with a perivisceral cavity, containing corpusculated blood. Respiration is effected by the general surface of the body, by gills, by pulmonary sacs, or by tubular involutions of the integument, termed 'tracheæ.' In no member of the division are vibratile cilia known to be developed. According to Professor Huxley, an additional constant character of the *Arthropoda* is to be found in the structure of the head, which is typically composed of six segments, and never contains less than four.

The *Arthropoda* are divided into four great classes, viz. the *Crustacea*, the *Arachnida*, the *Myriapoda*, and the *Insecta*; which are roughly distinguished as follows:—

1. CRUSTACEA.—*Respiration by means of gills, or by the general surface of the body. Two pairs of antennæ. Locomotive appendages more than eight in number, borne by the segments of the thorax, and usually of the abdomen also.*

2. ARACHNIDA.—*Respiration by pulmonary vesicles, by tracheæ, or by the general surface of the body. Head and thorax united*

into a cephalothorax. Antennæ (as such) absent. Legs eight. Abdomen without articulated appendages.

3. Myriapoda.—*Respiration by tracheæ; head distinct; remainder of the body composed of nearly similar somites. One pair of antennæ. Legs numerous.*

4. Insecta.—*Respiration by tracheæ. Head, thorax, and abdomen distinct. One pair of antennæ. Three pairs of legs, borne on the thorax. Abdomen destitute of limbs. Generally two pairs of wings on the thorax.*

CHAPTER XXXI.

CRUSTACEA.

Class I. Crustacea.—The members of this class are commonly known as Crabs, Lobsters, Shrimps, King-crabs, Barnacles, Acorn-shells, &c. They are nearly allied to the succeeding order of the *Arachnida* (Spiders and Scorpions); but may usually be distinguished by the possession of articulated appendages upon the abdominal segments, by the possession of two pairs of antennæ, and by the presence of branchiæ.

'In the *Crustacea* the body is distinguishable into a variable number of "somites," or definite segments, each of which may be, and some of which always are, provided with a single pair of articulated appendages. . . . . In most Crustacea, and probably in all, one or more pairs of appendages are so modified as to subserve manducation. A pair of ganglia is primitively developed in each somite, and the gullet passes between two successive pairs of ganglia, as in the *Annelida.*

'No trace of a water-vascular system, nor of any vascular system similar to that of the *Annelida*, is to be found in any Crustacean. All *Crustacea* which possess definite respiratory organs have branchiæ or outward processes of the wall of the body, adapted for respiring air by means of water; the terrestrial *Isopoda*, some of which exhibit a curious rudimentary representation of a tracheal system, forming no real exception to this rule. When they are provided with a circulatory organ, it is situated on the opposite side of the alimentary canal to the principal chain of ganglia of the nervous system; and communicates by valvular apertures with the surrounding venous sinus—the so-called "pericardium." '—(Huxley.)

In addition to these characters, the body in the *Crustacea* is always protected by a chitinous or sub-calcareous exoskeleton, or 'crust,' and the number of pairs of articulated limbs is generally from five to seven. They all pass through a series of metamorphoses, before attaining their adult condition, and every part that is found in an embryonic form, even though only temporarily developed, may be represented in a permanent condition in some member of a lower order.

The classification of the Crustacea is extremely complicated, and hardly any two writers adhere to the same arrangement. The tabular view which follows embodies the arrangement which appears to be most generally adopted, and the diagnostic characters of each order will be briefly given, a more detailed description being reserved for the more important divisions of the class. Before proceeding further, however, it will be as well to give a description of the morphology of a typical *Crustacean*, selecting the Lobster as being as good an example as any.

The body of a typical *Crustacean* may be divided into three regions—a *head*, a *thorax*, and an *abdomen*, each of which is composed of a certain number of somites, though opinions differ both as to the number of segments in each region, and as to their number collectively. By the majority of writers the body is looked upon as being typically composed of *twenty-one* segments, of which seven belong to the head, seven to the thorax, and seven to the abdomen. In many *Crustacea*, however, the segments of the head and thorax are welded together into a single mass, called the 'cephalothorax;' in which case the body shows only two distinct divisions, of which the cephalothorax claims fourteen segments, whilst the remaining seven are allotted to the abdomen. By Professor Huxley, on the other hand, the terminal joint of the abdomen, termed the 'telson,' is regarded as an *appendage*, and not as a somite. Upon this view, the body of a typical Crustacean will consist of *twenty* segments only. Professor Huxley, further, differs from the above-mentioned view, in the allotment of the somites, and he divides the body into six cephalic, eight thoracic, and six abdominal somites.

Whilst the normal number of segments in the body of any Crustacean may thus be regarded as being twenty-one, or twenty, there occur cases in which this number is exceeded, and others in which the number of somites is apparently less. In these latter cases, however, the apparent diminution in the number of segments is really due to some having been fused together, as is shown by the number of appendages, since each pair of appendages indicates a separate somite. In other cases, however, in which the number of somites is really less than the normal, this is due to an arrest of development. According to Milne-Edwards :—

'In the embryo these segments are formed in succession from before backwards, so that, when their evolution is checked, the later, rather than the earlier, rings are those which are wanting; and, in fact, it is generally easy to see in those specimens of full-grown Crustaceous animals whose bodies present fewer than twenty-one segments, that the anomaly depends on the absence of a certain number of the most posterior rings of the body.'

In no single example can a general view be obtained of the different segments and their appendages in the *Crustacea*. 'Indeed, the only segment that may be said to be persistent, is that which supports the mandibles, for the eyes may be wanting, and the antennæ, though less liable to changes than the remaining appendages, are nevertheless subject to very extraordinary modifications, and have to perform functions equally various. Being essentially and typically organs of touch, hearing, and perhaps of smell, in the highest Decapods, they become converted into burrowing organs in the *Scyllaridæ*, organs of prehension in the *Merostomata*, claspers for the male in the *Cyclopoidea*, and organs of attachment in the *Cirripedia*. Not to multiply instances, we have presented to us in the *Crustacea* probably the best zoological illustration of a class, constructed on a common type, retaining its general characteristics, but capable of endless modification of its parts, so as to suit the extreme requirements of every separate species.'—(H. Woodward.)

Taking the common Lobster as a good and readily obtainable type of the *Crustacea*, the body is at once seen to be composed of two parts, familiarly called the 'head' and the 'tail,' the latter being jointed and flexible. The so-called 'head' is really composed of both the head, properly so called, and the thorax, which have coalesced so as to form a single mass, technically called the 'cephalothorax.' The so-called 'tail,' on the other hand, is truly the 'abdomen.' The various appendages of the animal are arranged along the lower surface of the body, and consist of the feelers, jaws, claws, legs, &c. The entire body, with the articulated appendages, is enclosed in a strong chitinous 'shell,' or exoskeleton, and the cephalothorax is covered by a great cephalic shield or plate, which is termed the 'carapace.'

Each segment of the body may be regarded as essentially composed of a convex upper plate, termed the 'tergum,' which is closed below by a flatter plate, called the 'sternum,' the line where the two unite being produced downwards and outwards, into a plate, which is called the 'pleuron,' or 'pleura' (*fig.* 49, 2).

Strictly speaking, the composition of the typical somite is considerably more complex, each of the primary arcs of the somite being really composed of four pieces. The tergal arc is composed of two central pieces, one on each side of the middle line of the body, united together, and constituting the 'tergum' proper. The superior arc is completed by two lateral pieces, one on each side of the tergum, which are termed the 'epimera.' In like manner, the ventral or sternal arc is composed of a central plate, composed of two pieces united together in the middle line, and constituting the 'sternum' proper; the arc being completed by two lateral pieces, termed the 'episterna.' These plates are usually more or less completely anchylosed together, and the true structure of the somite in these cases is often shown by what are called 'apodemata.' These are septa which proceed inwards from the internal surface of the somite, penetrating more or less deeply between the various organs enclosed by the ring, and always proceeding from the line of junction of the different pieces of the segment (*fig.* 48).

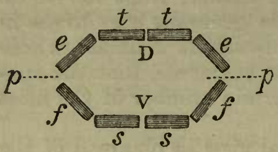


Fig. 48.—Theoretical figure illustrating the composition of the tegumentary skeleton of the Crustacea (after Milne-Edwards). D. Dorsal arc; *t t*. Tergal pieces; *e e*. Epimeral pieces; V, Ventral arc: *s s*. Sternal pieces; *f f*. Episternal pieces; *p p*. Insertion of the extremities.

It must be borne in mind that though the so-called 'head,' that is to say the 'cephalothorax,' of the Lobster is produced by an amalgamation of the various somites of the head and thorax, this is not the case with the great shield which covers this portion of the body. This shield—the so-called 'cephalic buckler,' or 'carapace'—is not produced by the union of the tergal arcs of the various cephalic and thoracic segments, as would at first sight appear to be to the case. On the contrary, the 'carapace' in the higher *Crustacea* is produced by an enormous development of the tergal pieces, or of the 'epimera' of one or two of the cephalic segments: the tergal arcs of the remaining somites being over-lapped by the carapace and remaining undeveloped

Examining the somites from behind forwards (for simplicity's sake), the last segment comes to be first described. This is the so-called 'telson,' which forms the last articulation of the abdomen, and never bears any appendages. For this reason, many authorities do not regard it as a somite, properly speaking, but simply as an azygos appendage—that is to say, as an appendage without a fellow. In the next segment (the last but one, or the last, of the abdomen, according to the view which is taken of the 'telson'), there is a pair of natatory appendages, called 'swimmerets.' Each swimmeret (*fig.* 49, 2) consists of a basal joint, which articulates with the sternum, and is called the 'protopodite' or propodite, and of two diverging joints, which are attached to the former; the outer of these being called the 'exopodite,' and the inner the 'endopodite.' In this particular segment, the exopodite and endopodite are greatly expanded, so as to form powerful paddles, and the exopodite is divided into two by a transverse joint. In the succeeding somites of the abdomen—with the exception

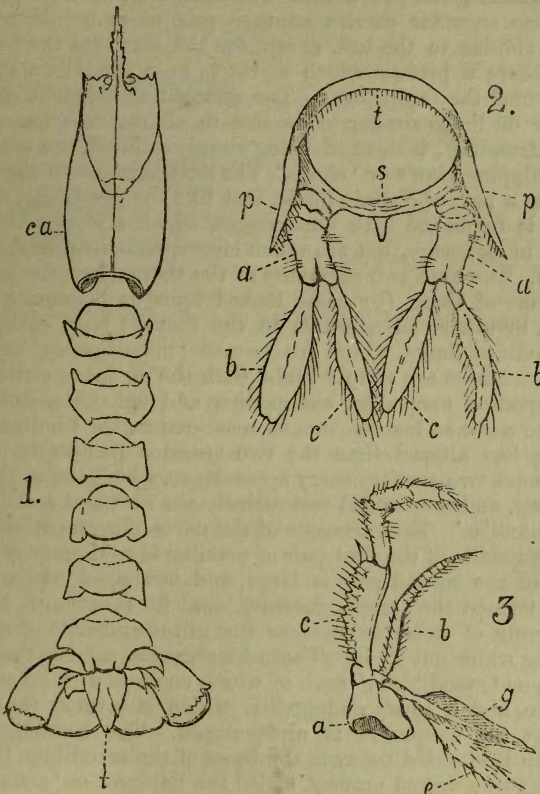


Fig. 49.—Morphology of Lobster. 1. Lobster with all the appendages, except the terminal swimmerets, removed, and the abdominal somites separated from one another. *ca*. Carapace; *t*. Telson. 2. The third abdominal somite separated. *t*. Tergum; *s*. Sternum; *p*. Pleuron; *a*. Protopodite; *b*. Exopodite; *c*. Endopodite. 3. One of the last pair of foot-jaws or maxillipedes. *e*. Epipodite; *g*. Gill; the other letters as before.

of the first, in which there is some modification—the appendages are in the form of swimmerets, essentially the same as those attached to the penultimate segment, and differing only in the fact, that the exopodite and endopodite are much narrower, and the former is undivided (*fig.* 49, 2). The last thoracic somite—immediately in front of the abdomen—carries a pair of the walking, or ambulatory, legs, each consisting of a short basal piece, or 'propodite,' and of a long jointed 'endopodite,' the 'exopodite' not being developed. The next thoracic segment carries another pair of ambulatory limbs, quite similar to the last, except for the fact that the protopodite bears a process which serves to keep the gills apart, and is termed the 'epipodite.' The succeeding segment supports a pair of limbs similar to the last in all respects, except that its extremities, instead of being simply pointed, are converted into nipping claws or 'chelæ.' The next segment of the thorax carries a pair of chelate limbs, just like the preceding, and the next is furnished with appendages, which are essentially the same in structure, but are much larger, constituting the great claws. The next two segments of the thorax, and the segment in front of these (by some looked upon as belonging to the head, by others as referable to the thorax) bear, each, a pair of modified limbs, which are termed 'maxillipedes,' or 'foot-jaws.' These are simply limbs with the ordinary structure of protopodite, exopodite, endopodite, and epipodite, but modified to serve as instruments of mastication, the hindmost pair being less altered than the two anterior pairs (*fig.* 49, 3). The next two somites carry appendages, which are in the form of jaws, and are termed respectively the first and second pairs of 'maxillæ.' Each consists of the parts afore-mentioned, but the epipodite of the first pair of maxillæ is rudimentary, whilst that of the second pair is large, and is shaped like a spoon. It is termed the 'scaphognathite,' and its function is to cause a current of water to traverse the gill-chamber by constantly baling water out of it. The next segment carries the biting jaws, or 'mandibles;' each of which consists of a large protopodite, and a small endopodite, which is termed the 'palp,' whilst the exopodite is undeveloped. The aperture of the mouth is situated between the bases of the mandibles, bounded behind by a forked process, called the 'labium,' or 'metastoma,' and in front by a single plate, called the 'labrum' (upper lip). The next segment bears the long antennæ, or feelers, each consisting of a short protopodite, and a long, jointed, and segmented endopodite, with a very rudimentary exopodite. In front of the great antennæ are the next pair of appendages, termed the 'antennules,' or smaller antennæ, each composed of a protopodite, and a segmented endopodite and exopodite, which are nearly of equal size. Finally, attached to the first segment of the head are the eyes, each of which is borne upon an eye-stalk formed by the protopodite. The gill-chamber is formed by a great prolongation downwards of the pleura of the thoracic segments, and the gills are attached to the bases of the legs.

TABULAR VIEW OF THE DIVISIONS OF THE CRUSTACEA.

Sub-class I. Epizoa (*Haustellata*).
Order 1. *Ichthyophthira*.

Sub-class II. Cirripedia.
Order 2. *Thoracica*. . . { Balanidæ. Verrucidæ. Lepadidæ.
„ 3. *Abdominalia*.
„ 4. *Apoda*.

Sub-class III. Entomostraca.
Order 5. *Ostracoda*.
„ 6. *Copepoda*.
} *Legion*, Lophyropoda.
„ 7. *Cladocera*.
„ 8. *Phyllopoda*.
„ 9. *Trilobita*.
} *Legion*, Branchiopoda.
„ 10. *Merostomata*.

Sub-class IV. Malacostraca.
Division a. Edriophthalmata.
Order 11. *Læmodipoda*.
„ 12. *Isopoda*.
„ 13. *Amphipoda*.
Division b. Podophthalmata.
Order 14. *Stomapoda*.
„ 15. *Decapoda*.
Tribe *a*. *Macrura*.
„ *b*. *Anomura*.
„ *c*. *Brachyura*.

CHAPTER XXXII.

EPIZOA AND CIRRIPEDIA.

Sub-class I. Epizoa (*Haustellata*).—The members of this sub-class of the *Crustacea* are in the adult state parasitic upon the bodies of fishes, and are usually deformed; but in the young condition they are locomotive, and are furnished with antennæ and eyes. The mouth is suctorial, and the limbs are terminated by suckers, hooks, or bristles. There are no differentiated respiratory organs, but respiration is performed by the surface of the body. The males are rudimentary, and are much smaller than the females, which are usually furnished with external ovisacs.

This division includes the single order *Ichthyophthira*, the characters of which are therefore the same as those of the sub-class, comprising various parasites upon fishes belonging to the genera *Lernœa*, *Achtheres*, *Peniculus*, &c.

ORDER 1. ICHTHYOPHTHIRA.—The members of this order are attached in the adult condition to the skin, eyes, or gills of fishes, and when mature possess an elongated body, having a more or less distinct head, and usually a pair of long, cylindrical ovisacs, depending from the extremity of the abdomen. Some adhere by a suctorial mouth, or by cephalic processes (*Cephaluna*); others are attached by a suctorial disc, developed at the extremities of the last pair of thoracic limbs, which are united together (*Brachiuna*), whilst in others (*Onchuna*) attachment is effected by hooks at the free extremities of the first pair of thoracic limbs.—(Owen.)

The males are usually not attached, but adhere to the females, of which, from their much smaller size, they appear to be mere parasites. The chief anatomical peculiarities of the female are the following:—The head is provided usually with a pair of jointed antennæ, and the body is divided into a cephalothorax and abdomen. The alimentary canal consists of a mouth, gullet, and intestine, terminating posteriorly in a distinct anus. The nervous system consists of a double ventral cord.

The embryo is free-swimming, and is provided with visual organs and locomotive appendages. The two sexes are now alike, and the conversion of the active embryo, or larva, into the swollen and deformed adult must be regarded as an instance of 'retrograde metamorphosis.'

SUB-CLASS II. CIRRIPEDIA.—This sub-class includes, amongst others, the common Acorn-shells, and the Barnacles or Goose-mussels. All the *Cirripedia* are distinguished by the fact, that, in the adult condition, they are permanently fixed to some solid object by the anterior extremity of the greatly metamorphosed head; the first three cephalic segments being much developed, and enclosing the rest of the body. The larva is free and locomotive, and the subsequent attachment, and conversion into the fixed adult, is effected by means of a peculiar secretion, or cement, which is discharged through the antennæ of the larva, and is produced by a special cement-gland, which is really a portion of the ovary. In the *Cirripedia*, therefore, the head of the adult is permanently fixed to some solid object, and the visceral cavity is protected by an articulated calcareous shell, or by a coriaceous envelope. The posterior extremity of the animal is free, and can be protruded at will through the orifice of the shell. This extremity consists of the abdomen, and of six pairs of forked, ciliated limbs, which are attached to the thorax, and serve to provide the animal with food. The two more important types of the *Cirripedia* are the Acorn-shells (*Balanidæ*) and the Barnacles (*Lepadidæ*). In the former the animal is sessile, the larval antennæ, through which the cement exudes, being imbedded in the centre of the membranous or calcareous 'basis' of the shell. In the latter the animal is stalked, and consists of a 'peduncle' and a 'capitulum.' The peduncle consists of the anterior extremity of the body, with the larval antennæ, usually cemented to some foreign body. The capitulum is supported upon the peduncle, and consists of a case composed of several calcareous plates, united by a membrane, enclosing the remainder of the animal.

Before giving a more detailed description of this singular and important sub-class, the following definition, as given by Owen, may be advantageously appended:—

'*Body*, chitinous, or chitino-testaceous, sub-articulated, mostly symmetrical, with aborted antennæ and eyes. *Mouth*, prominent, composed of a labrum, palpi, two mandibles, and two pairs of maxillæ. *Thorax*, attached to the sternal, internal surface of the carapace, with six pairs of multi-articulate, biramous, setigerous limbs. *Abdomen*, rudimentary. Vascular system diffused; white blood. Branchiæ, when present, attached to the inferior lateral part of the surface. Most are hermaphrodite; a few have minute, rudimentary, male individuals parasitically attached to the females. *Penis* proboscidiform, multiarticulate, attached to the hinder end of the abdomen. No oviducts. *Metamorphosis* and *metagenesis*, resulting in a permanent, parasitic attachment of the fully developed female or hermaphrodite individual.'

As regards the development of the *Cirripedia*, the larva is at first oval in shape, devoid of segmentation, and protected by a dorsal carapace. There is a single eye, two pairs of antennæ, and three pairs of natatory limbs, of which the two posterior pairs are bifid at their extremities. The larva, in fact, in this stage very closely resembles some of the smaller *Entomostraca*. In a more advanced stage, the carapace becomes considerably altered, the great antennæ become modified for prehension, the first pair of antennæ (antennules) disappears, and the eye becomes double. In a still more advanced condition, the anterior pair of natatory limbs become bifid, like the posterior ones; three additional pairs of limbs are developed behind those already existing; the abdomen becomes defined from the thorax; and the carapace is composed of two portions, or valves, which enclose the thorax and abdomen with their appendages. Finally, the young Cirripede fixes itself to some solid object by means of the prehensile antennæ. 'The "cement-ducts" can be traced as far as the third or "disc-segment" of the antennæ. There the cement seems to transude and fasten down the disc; soon both antennæ are surrounded by a common border of cement, which gradually increases in extent after the metamorphosis. In the *Lepas fascicularis* the cement is poured forth in sufficient quantities to form, itself, the substance to which the peduncle of the adult barnacle adheres, and, for a cluster of which barnacles it constitutes a central vesicular float.'—(Owen.) The cement-gland, as shown by Darwin, is 'part of, and continuous with, the branching ovaria,' and the cement-ducts open through the prehensile antennæ.

The form of the adult, as already said, differs considerably, but the two most important types are those presented respectively by the Sessile, and by the Pedunculated *Cirripedia.*

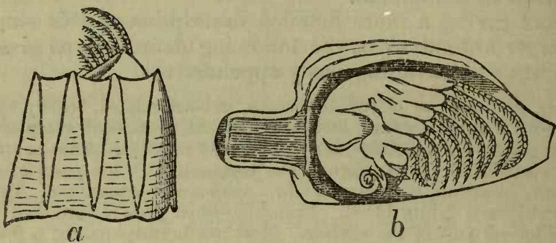


Fig. 50.—*Morphology of Cirripedia.* **a.** Sessile Cirripede or Balanoid, *Balanus sulcatus.* *b.* Pedunculate Cirripede or Lepadoid, *Lepas anatifera.*

In the common Acorn-shells (*Balani*, *fig.* 50, *a*) the anterior portion of the head is not elongated, but is fixed to the centre of a basal, membranous, or shelly plate, termed the 'basis,' which adheres by its external surface to some solid body. Above the basis rises a more or less limpet-shaped, or conical, shell, which is open at the top, but is capable of being completely closed by a pyramidal lid, or 'operculum.' Both the shell itself and the operculum are composed of calcareous plates, usually differing from one another in shape, and distinguished by special names. Within the shell the animal is fixed, head downwards. The thoracic segments, six in number, bear six pairs of limbs, each of which consists of a jointed protopodite and a much segmented exopodite and endopodite, both of which are ciliated, and constitute the so-called 'cirri,' from which the name of the sub-class is derived. These twenty-four cirri—the 'glass hand' of the *Balanus*—are in incessant action, being protruded from the opening of the shell, and again retracted within it, constantly producing currents of water, and thus bringing food to the animal. There are no specialised respiratory organs in the family of the *Balanidæ*.

In the Barnacles (*Lepadidæ*, *fig.* 50, *b*) the anterior extremity of the animal is enormously elongated, forming with the prehensile antennæ, the cement-ducts, and their exudation, a long stalk or peduncle, whereby the animal is attached to some solid object. At its free extremity the peduncle bears the 'capitulum,' which corresponds to the shell of the Balanoids, and is composed of various calcareous plates, united together by a membrane, moved upon one another by appropriate muscles, and protecting in their interior the body of the animal with its appendages. The thorax and limbs resemble those of the *Balanus*; but 'slender appendages, which from their position and connections are homologous with the branchiæ of the higher *Crustacea*, are attached to, or near to, the bases of a greater or less number of the thoracic feet, and extend in an opposite direction outside the visceral sac.'—(Owen.)

All the *Balanidæ* are hermaphrodite, and this is also the case with most of the *Lepadidæ*, but some extraordinary exceptions occur in this latter order. Thus, in some species of *Scalpellum* the individual forming the ordinary shell is female, and each female has two males lodged in transverse depressions within the shell. These males 'are very singular bodies; they are sac-formed, with four bead-like, rudimental valves at their upper ends; they have a conspicuous internal eye; they are absolutely destitute of a mouth, or stomach, or anus; the cirri are rudimental and furnished with straight spines, serving apparently to protect the entrance of the sac; the whole animal is attached like the ordinary Cirripede, first by the prehensile antennæ, and afterwards by the cementing-substance; the whole animal may be said to consist of one great sperm-receptacle, charged with spermatozoa; as soon as these are discharged, the animal dies.'

'A far more singular fact remains to be told; *Scalpellum vulgare* is, like ordinary Cirripedes, hermaphrodite, but the male organs are somewhat less developed than is usual; and, as if in compensation, several short-lived males are almost invariably attached to the occludent margin of both scuta. . . . I have called these beings *complemental males*, to signify that they are complemental to an hermaphrodite, and that they do not pair like ordinary males with simple females.'—(Darwin.)

DIVISIONS OF CIRRIPEDIA.—(AFTER DARWIN.)

ORDER I. THORACICA.

Carapace, either a capitulum on a pedicle, or an operculated shell with a basis. *Body*, formed of six thoracic segments, generally furnished with six pairs of limbs; abdomen rudimentary, but often bearing caudal appendages. *Mouth*, with labrum not capable of independent movements. *Larva*, firstly one-eyed, with three pairs of legs; lastly two-eyed, with six pairs of legs.

Fam. 1. *Balanidæ.*

Sessile, without a peduncle; scuta and terga (forming the *operculum*) provided with depressor muscles; the rest of the valves immovably united together.

Fam. 2. *Verrucidæ.*

Sessile. Shell asymmetrical, with scuta and terga, which are movable, but not furnished with a depressor muscle.

Fam. 3. *Lepadidæ.*

Pedunculated. *Peduncle* flexible, provided with muscles. Scuta and terga, when present, not furnished with a depressor muscle. Other valves, when present, not united into a single immovable case.

ORDER II. ABDOMINALIA.

Carapace flask-shaped; body formed of one cephalic, seven thoracic, and three abdominal segments, the latter bearing three pairs of cirri, but the thoracic segments being without limbs. *Mouth*, with the labrum greatly produced, and capable of independent movements. *Larva*, firstly egg-shaped, without external limbs, or an eye; lastly binocular, without thoracic limbs, but with abdominal appendages.

Genus. *Cryptophialus.*

ORDER III. APODA.

Carapace, reduced to two separate threads, serving for attachment. *Body* consisting of one cephalic, seven thoracic, and three abdominal segments, all destitute of cirri. Mouth suctorial.

Genus. *Proteolepas.*

CHAPTER XXXIII.

SUB-CLASS ENTOMOSTRACA.

SUB-CLASS III. ENTOMOSTRACA.—The term *Entomostraca* has been variously employed, and few authorities include exactly the same groups of the *Crustacea* under this name. By most the division is simply defined as including all those *Crustacea* in which the segments of the thorax and abdomen, taken together, are more or fewer than fourteen in number—the parasitic *Epizoa* and the *Cirripedia* being excluded. By Professor Rupert Jones the following definition of the *Entomostraca* has been given :—

'Animal aquatic, covered with a shell, or carapace, of a horny consistency, formed of one or more pieces, in some genera resembling a cuirass or buckler, and in others a bivalve shell, which completely or in great part envelops the body and limbs of the animal; in other genera the animal is invested with a multivalve carapace, like jointed plate-armour; the branchiæ are attached either to the feet or to the organs of mastication; the limbs are jointed, and more or less setiferous. The animals, for the most part, undergo a regular moulting or change of shell, as they grow; in some cases this amounts to a species of transformation.'

The *Entomostraca* are divided into two great divisions, or 'legions,' the *Lophyropoda* and the *Branchiopoda*, with which the order *Merostomata* may be conveniently considered.

DIVISION A. LOPHYROPODA.—The members of this division possess few branchiæ, and these are attached to the appendages of the mouth. The feet are few in number, and mainly subserve locomotion; the carapace is in the form either of a shield protecting the cephalothorax, or of a bivalve shell enclosing the entire body. The mouth is not suctorial, but is furnished with organs of mastication.

This division comprises the two orders *Ostracoda* and *Copepoda*.

ORDER I. OSTRACODA.—Small Crustaceans having the entire body enclosed in a shell or carapace, which is composed of two valves united along the back by a membrane. The branchiæ are attached to the posterior jaws, and there are only two or three pairs of feet, which subserve locomotion, but are not adapted for swimming.

The order includes the *Cyprides*, which are of almost universal occurrence in fresh water. The common *Cypris* is completely protected from its enemies by a bivalve carapace, which it can open and shut at will, and out of which it can protrude its feet. Locomotion is mainly effected by means of a pair of caudal appendages. The *Cypris* is extremely prolific, and a single impregnation appears to last the female for its entire lifetime. It appears, also, that the young females, produced in this way, are capable for some generations of producing fresh individuals without the influence of a male (parthenogenesis).

ORDER II. COPEPODA.—Small Crustaceans, having the head and thorax covered by a carapace, and furnished with five pairs of natatory feet. Usually there are two caudal locomotive appendages.

In the *Cyclops*, which is one of the commonest of the 'Water-fleas,' the cephalothorax is protected superiorly by a carapace, and the abdominal somites are conspicuous. In front of the head is situated a single large eye, behind which are the great antennæ and the antennules. The feet are five pairs in number, each consisting of a protopodite and a segmented exopodite and endopodite, usually furnished with hairs and forming an efficient swimming apparatus. The young pass through a metamorphosis, and are not capable of reproducing the species until after the third moult or change of skin. The female *Cyclops* carries externally two ovisacs, in which the ova remain till they are hatched. A single congress with the male is apparently sufficient to fertilise the female for life.

The *Copepoda*, or Oar-footed Crustaceans, are all of small size, and are of common occurrence in fresh water in all parts of Europe.

DIVISION B. BRANCHIOPODA.—The Crustaceans included in this division have many branchiæ, and these are attached to the legs, which are often numerous, and are formed for swimming. The body is either naked, or is protected by a carapace, which may enclose either the entire body, or the head and thorax only. The mouth is provided with organs of mastication.

The *Branchiopoda* comprise the *Cladocera*, the *Phyllopoda*, and probably the *Trilobita*, though this order departs in many respects from the above definition. The *Merostomata* may be considered along with these, though these, too, are in many respects peculiar.

ORDER I. CLADOCERA.—The members of this order are small Crustaceans, which have a distinct head, and have the whole

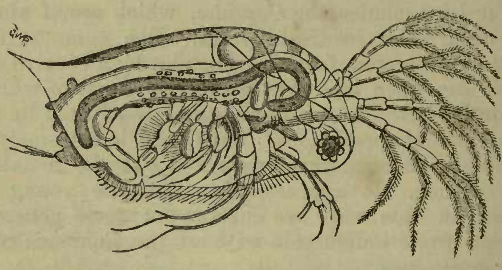


Fig. 51.—Cladocera. *Daphnia pulex*, the common Water-flea (male), greatly enlarged.

of the remainder of the body enclosed within a bivalve carapace, similar to that of the *Ostracoda*. The feet are few in number (usually four or five pairs), and are mostly respiratory, carrying the branchiæ. Two pairs of antennæ are present, the larger pair being of large size, branched, and ting as natatory organs.

in the *Daphnia pulex* (*fig.* 51), or 'branched-horned Water-flea,' which occurs commonly in our ponds, the body is enclosed in a bivalve shell, which is not furnished with a hinge posteriorly, and which opens anteriorly for the protrusion of the feet. The head is distinct, not enclosed in the carapace, and carrying a single eye. The mouth is situated on the under surface of the head, and is provided with two mandibles and a pair of maxillæ. The gills are in the form of plates, attached to the five pairs of thoracic legs. The males are very few in number, compared with the females, and a single congress is all that is required to fertilise the female for life. Not only in this case, but the young females produced from the original fecundated female appear to be able to bring forth young without having access to a male. In this way the influence of a single fecundation appears to be transmitted through several generations.

ORDER II. PHYLLOPODA.—*Crustacea*, mostly of small size, the carapace protecting the head and thorax, or the body entirely naked. Feet numerous, never less than eight pairs, mostly foliaceous or leaf-like, branchial in function. The eyes sometimes confluent, sometimes distinct and sub-pedunculate.

The *Phyllopoda* are chiefly interesting from their affinity to the extinct Trilobites. In the typical genera *Limnadia* and *Apus*, the body is protected by a carapace which is bivalve in the former and shield-like in the latter. In *Limnadia* the carapace covers the greater part of the body, and opens along the ventral margin. There are from 18 to 30 pairs of membranaceous and respiratory feet. In *Apus* the carapace is clypeiform and covers a portion of the abdomen, and there are sixty pairs of feet, of which all but the first pair are foliaceous.

In *Branchipus*, which occurs in many pools, the body is not protected by a carapace, and this is also the case with the singular little *Artemia salina* which inhabits the brine-pans at Lymington and elsewhere.

ORDER III. TRILOBITA.—This order is entirely extinct, none of its members having survived the close of the Palæozoic period. It is probable that the Trilobites should be placed near the *Phyllopoda*, but their exact position is uncertain, as no traces of any appendages of any kind, except the labrum, have hitherto been discovered in any Tribolite.

The body of a Trilobite (*fig.* 52), was covered with a 'crust,' or exoskeleton, which shows more or less markedly a division into three longitudinal lobes, from the presence of which the name of the order is derived. The shell is composed of a cephalic shield, a certain number of free and movable thoracic rings, and a caudal shield, or 'pygidium,' the rings of which are more or less completely anchylosed. On the under surface of the body nothing has hitherto been discovered, except the 'hypostome,' or 'labrum,' which was a plate placed in front of the mouth. No traces of ambulatory or natatory limbs, of branchiæ, or of antennæ, have ever been discovered. The eyes, when present, are compound, and usually sessile, but are sometimes supported upon projecting processes. It has generally been supposed that the body of the Trilobite occupied the median lobe of the crust, commencing with the 'glabella' in front, and terminating with the 'pygidium' behind; whilst the axial lobes protected a series of delicate respiratory feet; but this view is doubted by many authorities, and the question is one which we have at present no means of deciding.

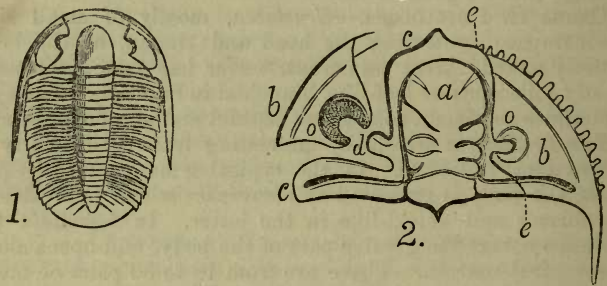


Fig. 52.—Morphology of Trilobites. 1. *Angelina Sedgwickii.* 2. Diagram of the cephalic shield of a Trilobite (after Salter). *a.* Glabella; *b b.* Free cheeks, bearing the eyes (*o o*); *c c.* Fixed cheek, including the eye-lobe (*d*); *e e.* Facial suture.

The cephalic shield of a typical Trilobite is more or less completely semicircular (*fig.* 52), and is composed of a central and of two lateral pieces, of which the two latter may, or may not, be united together in front of the former.

The median portion is usually elevated above the remainder of the cephalic shield, and is called the 'glabella;' it protected the region of the stomach, and is usually divided into from three to four lobes by lateral grooves. At each side of the glabella, and continuous with it, is a small semicircular area, called the 'fixed cheek.' The glabella, with the 'fixed cheeks,' is separated from the lateral portions of the cephalic shield—termed the 'movable,' or 'free cheeks,'—by a peculiar suture or line of division, which is known as the 'facial suture,' and is quite unknown amongst recent *Crustacea*, except for a faint indication in the *Limulus*, and more or less doubtful traces in certain other forms. The movable cheeks bear the eyes, which are generally crescentic or reniform in shape, are rarely pedunculated, and consist of an aggregation of facets covered by a thin cornea. The facial sutures may join one another in front of the glabella—in which case the free cheeks will form a single piece—or they may cut the anterior margin of the shield separately—in which case the free cheeks will be discontinuous. The posterior angles of the free cheeks are often produced into long spines.

Behind the cephalic shield comes the thorax, composed of a variable number of segments, which are not soldered together, but are capable of free motion upon one another, so as to allow the animal to roll itself up after the manner of a wood-louse, or hedgehog. The thorax is usually strongly trilobed, and each thorax-ring shows the same trilobation, being composed of a central, more or less strongly convex, portion, called the 'axis,' and of two flatter side-lobes, called the 'pleuræ.'

The 'pygidium,' or 'tail,' is usually trilobed, also, and, like the thorax, consists of a median axis and of a marginal limb, the composition of the whole out of anchylosed segments being shown by the existence of axial and pleural grooves.

ORDER IV. MEROSTOMATA.—The members of this order are *Crustacea*, often of gigantic size, in which the mouth is furnished with mandibles and maxillæ, the terminations of which become walking- or swimming-feet, and organs of prehension.

This order comprises the recent King Crabs, and the extinct *Pterygoti* and *Eurypteri*.

SUB-ORDER I. XIPHOSURA (*Pœcilopoda*).—'Crustacea having the anterior segments welded together to form a broad convex buckler, upon the dorsal surface of which are placed the compound eyes and ocelli; the former sub-centrally, the latter in the centre in front. The mouth is furnished with a small labrum, a rudimentary metastoma and six pairs of appendages. Posterior segments of the body more or less free, and bearing upon their ventral surfaces a series of broad lamellar appendages; the telson, or terminal segment, ensiform.'—(Henry Woodward.)

The *Xiphosura* include no other recent forms than the *Limuli* (King Crabs, or Molucca Crabs) (*fig.* 53). They are distinguished by the possession of *six pairs of chelate limbs, placed round the mouth, having their bases spinous and officiating as jaws.* Six other pairs of foliaceous appendages are attached to the abdomen, and the last five of these carry branchiæ. The body, which is often of great size, when viewed from above exhibits a division into three portions:—(1) An anterior semicircular shield, which carries two compound and two simple eyes; (2) a posterior, irregularly hexagonal shield which covers the abdomen; and (3) a long, sword-like telson, articulated to the dorsal buckler, and giving the name to the sub-order.

The chief features, therefore, which characterise the *Limulus* are as follows:—1. The possession of six pairs of appendages which are placed round the mouth, have their bases spinous, act as jaws, and have their free extremities developed into laws; 2. The possession of six abdominal pairs of appendages, expanded for swimming, and carrying the gills; 3. The possession of a semicircular buckler, covering the cephalothorax, and

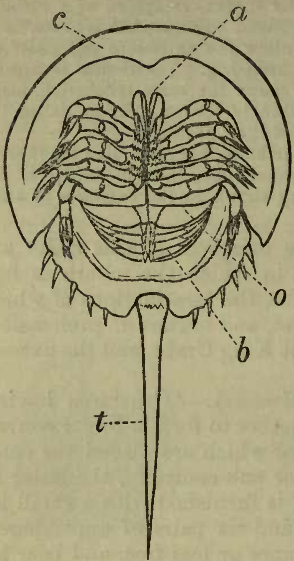


Fig. 53.—Xiphosura. *Limulus polyphemus*, viewed from below. *c*. The cephalic shield carrying the sessile eyes upon its upper surface; *o*. 'Operculum,' covering the reproductive organs; *b*. Branchial plates; *a*. First pair of antennæ (antennules) ending in chelæ. Below these is the aperture of the mouth surrounded by the spiny bases of the remaining five pairs of appendages, which are regarded by Woodward as being respectively, from before backwards, the great antennæ, the mandibles, the first maxillæ, the second maxillæ, and a pair of maxillipedes. All have their extremities chelate.

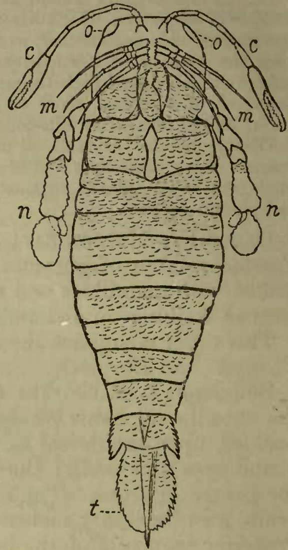


Fig. 54.—Eurypterida. *Pterygotus Anglicus*, restored (after H. Woodward). *c c*. Chelate antennæ; *o o*. Eyes, situated at the anterior margin of the carapace; *m m*. The mandibles, and first and second maxillæ; *n n*. The maxillipedes; the basal margins of these are serrated, and are drawn as if seen through the metastoma or post-oral plate which serves as a lower lip. Immediately behind this is seen the operculum or thoracic plate which covers the two anterior thoracic somites. Behind this are five thoracic, and five abdominal somites, and lastly there is the telson (*t*).

carrying the eyes upon its upper surface; 4. The possession of a second buckler, or 'operculum,' covering the abdomen; 5. The presence of a long, sword-shaped telson, or tail-spine, articulated to the dorsal shield.

The larval *Limulus* does not possess the ensiform post-anal spine of the adult.

SUB-ORDER 2. EURYPTERIDA.—'Crustacea with numerous, free, thoracico-abdominal segments, the first and second (?) of which bear one or more broad lamellar appendages upon their ventral surface, the remaining segments being devoid of appendages;

anterior rings are united into a carapace, bearing a pair of larval eyes (*ocelli*) near the centre, and a pair of large, marginal, or sub-central eyes; the mouth furnished with a broad post-oral plate, or *metastoma*, and five pairs of movable appendages, the posterior of which form great swimming feet; the telson, or terminal segment, extremely variable in form; the integument characteristically sculptured.'—(Henry Woodward.)

The *Eurypterida* are all extinct, and are entirely confined to the Palæozoic period. Many of them attained to a comparatively gigantic size; *Pterygotus Anglicus* (*fig.* 54) being supposed to have reached a length of probably six feet. In their characters they present many larval features; resembling the larvæ of the *Decapoda*, especially in the fact that all the free somites (except the two anterior ones) were totally devoid of appendages.

CHAPTER XXXIV.

MALACOSTRACA.

Sub-class IV. Malacostraca.—The *Crustacea* of this sub-class are distinguished by the possession of a generally *definite* number of body-segments; seven somites going to make up the thorax, and an equal number entering into the composition of the abdomen (counting, that is, the telson as a somite). The *Malacostraca* are divided into two primary divisions, termed respectively the *Edriophthalmata* and the *Podophthalmata*, according as the eyes are sessile, or are supported upon eye-stalks.

Division A. Edriophthalmata.—This division comprises those *Malacostraca* in which the eyes are sessile, and the body is not protected by a carapace. It comprises the three orders, *Læmodipoda*, *Isopoda*, and *Amphipoda*.

Order I. Læmodipoda.—The *Læmodipoda* are small Crustaceans, which are distinguished amongst the *Edriophthalmata* by the rudimentary condition of the abdomen. The first thoracic segment is amalgamated with the head, and the limbs of this segment appear to be inserted beneath the head, or, as it were, beneath the throat; hence the name given to the order. The respiratory organs are in the form of two or three pairs of membranous vesicles attached to the segments of the thorax, or to the bases of the legs. The *Læmodipoda* do not swim, and one section of the order comprises parasitic Crustaceans, of which the Whale-louse (*Cyamus Ceti*) is the most familiar.

ORDER II. AMPHIPODA.—The members of this order resemble those of the preceding in the nature of the respiratory organs, which consist of membranous vesicles attached to the bases of the thoracic limbs. The first thoracic segment, however, is distinct from the head, and the abdomen is well developed, and is composed of seven segments. There are seven pairs of thoracic limbs, directed partly forwards, and partly backwards, the name of the order being derived from this circumstance.

Fig. 55.—Amphipoda. The Sand-hopper, *Talitrus locusta*, enlarged.

All the *Amphipoda* are small, the 'Sand-hopper' (*Talitrus locusta*, *fig.* 55) and the 'fresh-water Shrimp' (*Gammarus pulex*) being two of the commonest forms.

ORDER III. ISOPODA.—In this order the head is always distinct from the segment bearing the first pair of feet. The respiratory organs are not thoracic, as in the two preceding orders, but are attached to the inferior surface of the abdomen, and consist of branchiæ, which in the terrestrial species are protected by plates which fold over them. The thorax is composed of seven segments, bearing seven pairs of limbs, which, in the females, have marginal plates, attached to their bases, and serving to protect the ova. The number of segments in the abdomen varies, but is never more than seven. The eyes are two in number, formed of a collection of simple eyes, or sometimes truly compound. Of the members of this order, many are aquatic in their habits, and are often parasitic, but others are terrestrial.

By Milne-Edwards the *Isopoda* are divided into three sections, termed respectively from their habits, the *Natatorial*, *Sedentary*, and *Cursorial* Isopods. In the *Natatorial Isopoda* the extremity of the abdomen and the last pair of abdominal legs are expanded so as to form a swimming tail. Some of this section are parasitic upon various fishes (*Cymothoa*), whilst others are found in the sea (*Sphæroma*). In the *Sedentary Isopoda* the animals are all parasitic, with short, incurved, hooked feet. This section includes the single family of the *Bopyridæ*, all the species of which live parasitically either in the gill-chambers, or attached to the ventral surface, of certain of the Decapod *Crustacea*, such as the Shrimps (*Crangones*) and the *Palæmones*.

The *Cursorial*, or running, *Isopods* mostly live upon the land, and are, therefore, destitute of swimming feet. The most familiar examples of this section are the common Wood-lice (*Oniscus*). Here, also, belongs the little *Limnoria terebrans*, so well known for the destruction which it produces by boring into the wood-work of piers and other structures placed in the sea.

Division B. Podophthalmata.—The members of this division have compound eyes supported upon movable stalks or peduncles, and the body is always protected by a cephalothoracic carapace. It comprises the two orders *Stomapoda* and *Decapoda*, of which the latter includes all the highest and most familiar examples of the class *Crustacea*.

Order I. Stomapoda.—In this order there are generally from six to eight pairs of legs, and the branchiæ, when present, are not enclosed in a cavity beneath the thorax, but are either suspended beneath the abdomen, or, more rarely, are attached to the thoracic legs. The shell, also, is thin, and often membranous. From all the preceding orders the *Stomapoda* are, of course, distinguished by the possession of pedunculate eyes.

All the Stomapods are marine, and *Squilla mantis* may be taken as a good example of the order. In this Crustacean the carapace is small, and the posterior half of the thorax is unprotected. Several of the anterior appendages are developed into powerfully prehensile and hooked feet. The branchiæ are attached to the first five pairs of abdominal feet. The three posterior thoracic and the abdominal appendages are in the form of 'swimmerets,' and the tail is expanded into a powerful fin.

Order II. Decapoda.—The members of this order are the most highly organised of all the *Crustacea*, as well as being those which are most familiarly known, the Lobsters, Crabs, Shrimps, &c. being comprised under this head. For the most part they are aquatic in their habits, and they are usually protected by strong, resisting shells. There is always a complicated set of 'gnathites,' or appendages modified for masticatory purposes, surrounding the mouth. The ambulatory feet are made up of five pairs of legs (hence the name of the order), the first pair—and often some other pairs behind this—being 'chelate,' or having their extremities developed into nipping claws. The branchiæ are pyramidal, and are contained in cavities at the sides of the thorax. The carapace is large, covering the head and thorax and the anterior part of the abdomen.

The *Decapoda* are divided into three tribes, termed respectively the *Macrura*, *Anomura* and *Brachyura*, and characterised by the nature of the abdomen.

TRIBE A. MACRURA.—The 'long-tailed' Decapods included in this tribe are distinguished by the possession of a well developed abdomen, often longer than the cephalothorax, the posterior extremity of which forms a powerful natatory organ or caudal fin. This section comprises the Lobster, Cray-fish, Shrimp, Prawn, &c., of which the Lobster may be taken as the type.

In the Lobster (*fig.* 49) the somites of the head and thorax are amalgamated into a single mass, the 'cephalothorax,' covered by a carapace or shield, which is developed from 'the lateral or epimeral elements of the fourth cephalic ring, which meet along the back, and give way preparatory to the moult. The tergal elements of the thoracic rings are not developed in either Crabs or Lobsters; when these rings are exposed by lifting up the cephalothoracic shield, the epimeral parts alone are seen, converging obliquely towards one another, but not joined at their apices.'—(Owen.)

The first segment of the head bears the compound eyes, which are supported upon long and movable eye-stalks or peduncles. Behind these come two pairs of jointed tactile organs, the larger called the 'great antennæ,' the smaller the 'antennules.' The mouth is situated on the under surface of the front of the head, and is provided from before backwards with an upper lip ('labrum'), two 'mandibles,' two pairs of 'maxillæ,' three pairs of 'maxillipedes' or 'foot-jaws,' and a bifid lower lip, or 'metastoma.' The five remaining segments of the thorax carry the five pairs of ambulatory legs, of which the first constitute the great claws, or 'chelæ;' the next two pairs are also chelate, though much smaller, and the last two pairs are terminated by simply pointed extremities. The segments of the abdomen carry each a pair of natatory limbs, or 'swimmerets,' the last pair being greatly expanded, and constituting, with the 'telson,' a powerful caudal fin. Most posteriorly of all is the post-anal plate, or 'telson,' which may be looked upon either as an azygos appendage, or as a terminal segment, which has no lateral appendages.

The mouth leads by a short œsophagus into a globose stomach, in the cardiac portion of which is a calcareous apparatus for triturating the food, which is commonly called the 'lady in the lobster.' The intestine is continued backwards from the stomach without convolutions, and the anal aperture is situated just in front of the telson. There is, also, a well developed liver, consisting of two lobes, which open by separate ducts into the intestine.

The heart is situated dorsally, and consists of a single contractile sac, which opens by valvular apertures into a surrounding venous sinus, inappropriately called the 'pericardium.' The heart is filled with oxygenated blood derived from the gills, and propels the aërated blood through every part of the body. The gills are pyramidal bodies attached to the bases of the legs, and protected by the sides of the carapace. They consist each of a central stem supporting numerous laminæ, and they are richly supplied with blood, but are not ciliated. The water which occupies the gill-chambers is renovated partly by the movements of the legs, and partly by the expanded epipodite of the second pair of maxillæ, which constantly spoons out the water from the front of the branchial chamber, and thus causes an entry of fresh water by the posterior aperture of the cavity.

The nervous system is of the normal 'homogangliate' type, consisting of a longitudinal series of ganglia of different sizes, united by commissural cords, and placed along the ventral surface of the body. The organs of sense consist of the two compound eyes, the two pairs of antennæ, and two auditory sacs.

The sexes are invariably distinct, and the generative products are conveyed to the exterior by efferent ducts, which open at the base of one of the pairs of thoracic legs. The ovum is 'meroblastic,' a portion only of the vitellus undergoing segmentation. The neural side of the body, that is to say, the ventral surface, appears on the surface of the ovum, so that the embryo is built up from below, and the umbilicus is situated posteriorly.

TRIBE B. ANOMURA.—The Decapods which belong to this tribe are distinguished by the condition of the abdomen, which is neither so well developed as in the *Macrura*, nor so rudimentary as in Crabs. Further, the abdomen does not terminate posteriorly in a caudal fin, as in the Lobster.

The most familiar of the *Anomura* are the Hermit-crabs (*Paguridæ*). In the common Hermit-crab (*Pagurus Bernhardus*) the abdomen is quite soft, and is merely enclosed in a membrane, so that the animal is compelled to protect itself by adopting the empty shell of some Mollusc, such as the common Whelk, which it changes at will, when too small. The Hermit is provided with a terminal caudal sucker, and with two or three pairs of rudimentary feet developed upon the abdomen, by means of which he retains his position within his borrowed dwelling. The carapace is not strong, but the claws are well developed, one being always larger than the other.

TRIBE C. BRACHYURA.—The 'short-tailed' Decapods, or Crabs, are distinguished from the two preceding tribes by the rudimentary condition of the abdomen, which is very short, and is tucked up beneath the cephalothorax, the latter being disproportionately large. The extremity of the abdomen is not provided with any appendage, and it is merely employed by the female to carry the ova. The Crabs (*fig.* 56) are mostly furnished with ambulatory limbs, and are not formed for swimming, most of them being littoral in their habits, and some few even living inland.

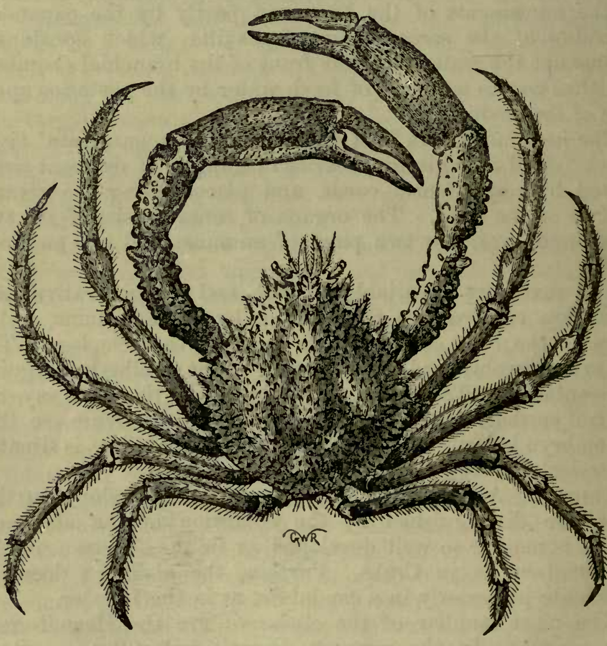


Fig. 56.—Brachyura. The Spiny Spider-Crab (*Maia squinado*).

In all the essential points of their anatomy the Crabs do not differ from the Lobster and the other *Macrura*; but they are decidedly higher in their organisation. This is especially seen in the disposition of the nervous system, the ventral ganglia in the Crab being concentrated into a single large ganglion, from which nervous filaments are sent to all parts of the body.

Reproduction in the Crabs is the same as in the *Macrura*, but the larva is exceedingly unlike the adult, and approximates closely to the type of the *Macrura*, another proof that the *Brachyura* stand higher in the Crustacean scale. The larval Crab was originally described as a distinct animal, under the name of *Zoea*, presenting in this condition a long and well developed abdomen.

CHAPTER XXXV.

DISTRIBUTION OF THE CRUSTACEA.

DISTRIBUTION OF CRUSTACEA IN SPACE.—The following general principles have been laid down by Milne-Edwards with regard to the geographical distribution of the *Crustacea*:—

1. The different forms and modes of organisation of the *Crustacea* are more varied and numerous, in proportion as we pass from the Polar Regions towards the Equator.

2. The number of different species is not only greater, but the number of types is greater in warm regions as compared with cold.

3. The higher *Crustacea* are either entirely wanting or are sparingly represented in the colder regions of the globe, but increase rapidly in relative numbers as the Equator is approached.

4. The size attained by the *Crustacea* is greater on the average in warm regions than in colder climates.

5. The special points of structure which are characteristic of the different groups of *Crustacea* are more strongly manifested in the warmer regions of the globe.

6. There exists a decided relation between the temperature of any given region and the character of its Crustacean fauna; similar *generic* forms being usually found occupying regions of the same climatal character.

DISTRIBUTION OF CRUSTACEA IN TIME.—The class *Crustacea* is largely represented in past time, ranging from the Cambrian Rocks up to the present day. The oldest families of the *Crustacea* are the *Trilobita* and the *Eurypterida*, both of which are exclusively Palæozoic, and died out at the close of the Carboniferous epoch. It is worthy of notice how larval are the characters of these ancient groups when compared with their modern successors. Of the remaining orders the *Cirripedia*, *Ostracoda* and *Phyllopoda* are the three which are most largely represented.

1. *Cirripedia.*—The Cirripedes are hardly known as Palæozoic fossils, but valves of a singular member of this order (*Turrilepas*) have been found in the Silurian Rocks of Scotland. With this exception, the Cirripedes are entirely confined in past time to the Secondary and Tertiary epochs. The *Balanidæ* are the most common, commencing, as far as is yet known, in the Eocene period, and attaining their maximum in recent seas. The *Verrucidæ* commence in the Chalk, and the *Lepadidæ* begin still lower, in the Jurassic Rocks, and attain their maximum of development in the Cretaceous epoch.

2. *Ostracoda.*—Small Ostracode *Crustacea* are extremely abundant as fossils in many formations, and extend from the Lower Silurian period up to the present day.

3. *Phyllopoda.*—Remains of Crustaceans supposed to belong to this order are found in the Palæozoic Rocks. *Hymenocaris* is found in the Upper Cambrian, *Caryocaris* in the Lower Silurian, *Ceratiocaris* in the Upper Silurian, and *Dithyrocaris* in the Carboniferous Limestone. All these forms, with other similar ones, are believed to be most closely allied to the recent *Apus* and *Nebalia.*

4. *Trilobita.* — The Trilobites are exclusively Palæozoic fossils. In the Upper Cambrian Rocks—the so-called 'primordial zone'—there occurs a singular group of Trilobites—the so-called primordial Trilobites—distinguished by the possession of many larval characters. In the Lower and Upper Silurian Rocks the Trilobites attain their maximum of development. They are still well represented in the Devonian Rocks; but they die out completely before the close of the Carboniferous epoch, being represented in the Mountain Limestone by three genera only (*Phillipsia*, *Brachymetopus* and *Griffithides*).

5. *Eurypterida.*—These, like the last, are entirely Palæozoic, attaining their maximum in the Upper Silurian and Devonian formations, and dying out in the Carboniferous Rocks. *Pterygotus*, *Eurypterus*, and *Slimonia* are the most characteristic genera.

6. *Xiphosura.*—The genus *Limulus* commenced, as far as is yet known, in the Permian period, and has survived up to the present day. Its first appearance, therefore, was just at the close of the Palæozoic Epoch. The two remaining genera, which constitute with *Limulus* this sub-order (viz. *Belinurus* and *Prestwichia*), are Palæozoic, and are not known to occur out of the Carboniferous Rocks.

7. *Isopoda.*—The earliest known Isopod is the *Prosoponiscus* of the Permian Rocks.

8. *Stomapoda.*—This order is doubtfully represented in the Carboniferous Rocks.

9. *Decapoda.*—The Decapods are not known to have existed at all during the Palæozoic period; but they are well represented, in all their three tribes, in the Secondary and Tertiary Epochs, attaining their maximum at the present day. The London Clay (Eocene) is especially rich in the remains of *Macrura* and *Brachyura.*

CHAPTER XXXVI.

ARACHNIDA.

Class II. Arachnida.—The *Arachnida*—including the Spiders, Scorpions, Mites, &c.—possess almost all the essential characters of the *Crustacea*, to which they are very closely allied. Thus, the body is divided into a variable number of somites, some of which are always provided with articulated appendages. A pair of ganglia is primitively developed in each somite, and the neural system is placed ventrally. The heart, when present, is always situated on the opposite side of the alimentary canal to the chain of ganglia. The respiratory organs, however, whenever these are differentiated, are never in the form of branchiæ as in the *Crustacea*, but are in the form either of pulmonary vesicles or sacs, or of ramified tubes, formed by an involution of the integument, and fitted for breathing air directly. Further, there are never 'more than four pairs of locomotive limbs, and the somites of the abdomen, even when these are well developed, are never provided with limbs;' the reverse being the case amongst the *Crustacea*. Lastly, 'in the higher *Arachnida*, as in the higher *Crustacea*, the body is composed of twenty somites, six of which are allotted to the head; but, in the former class, one of the two normal pairs of antennæ is never developed, and the eyes are always sessile; while, in the higher *Crustacea*, the eyes are mounted upon movable peduncles, and both pairs of antennæ are developed.'—(Huxley.)

The head in the *Arachnida* is always amalgamated with the thorax, to form a 'cephalothorax;' the integument is usually chitinous, and the locomotive limbs are mostly similar in form to those of insects, and are usually terminated by two hooks.

In many of the *Arachnida* the integument remains soft over the entire body: in others, as in the majority of Spiders, the abdomen remains soft and flexible, whilst the cephalothorax is more or less hard and chitinous; in the Scorpions, again, the integument over the whole body forms a strong chitinous shell.

The typical somite of the *Arachnida* is constituted upon exactly the same plan as that of the *Crustacea*, consisting essentially of a dorsal and ventral arc; the former composed of a central piece, or 'tergum,' and of two lateral pieces, or 'epimera;' whilst the latter is made up of a median 'sternum' and of two lateral 'episterna.'

As regards the composition of the cephalothorax of Spiders, 'the tergal elements of the coalesced segments are wanting, and the back of the thorax is protected by the elongation, convergence, and central confluence of the epimeral pieces; the sternal elements have coalesced into the broad plate in the centre of the origins of the ambulatory legs, from which it is separated by the episternal elements. . . . . The non-development of the tergal elements explains the absence of wings.'—(Owen.)

The mouth is situated, in all the *Arachnida*, in the anterior segment of the body, and is surrounded by suctorial or masticatory appendages. In the higher *Arachnida* the mouth is provided from before backwards with the following appendages (*fig.* 57, 4). 1. A pair of 'mandibles,' used for prehension. 2. A pair of 'maxillæ,' each of which is provided with a long jointed appendage, the 'maxillary palp.' 3. A lower lip, or 'labium.' In the Scorpion an upper lip, or 'labrum,' is also present.

In the Spiders (*fig.* 57) each mandible terminates in a sharp, movable hook, which possesses an aperture at its extremity communicating by a canal with a gland, which is placed in the preceding joint of the mandible, and secretes a poisonous fluid. The maxillary palps in the Spiders are long, jointed appendages, terminated in the females by pointed claws, but frequently swollen, and carrying a special sexual apparatus in the males.

In the Scorpions (*fig.* 57, 1) the mandibles are short, and terminate in strong pincers, or 'cheliceræ.' The maxillary palpi are, also, greatly developed, and constitute powerful grasping claws, or 'chelæ.' In the genus *Galeodes*, the mandibles, like those of the Scorpion, constitute 'cheliceræ,' though comparatively much larger and longer; but the maxillary palps are not developed into 'chelæ.'

With regard to antennæ, these organs, *as such*, do not exist in the *Arachnida*. It is generally believed, however, that the *mandibles* of the *Arachnida* are truly homologues, not of the parts which bear the same name in the other *Arthropoda*, but of the *antennæ*. The antennæ, therefore, of the Spiders are

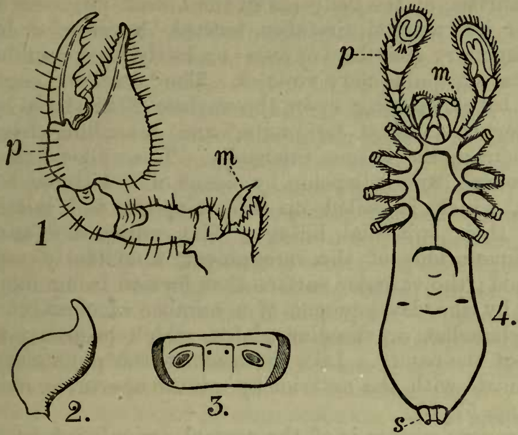


Fig. 57.—Morphology of Arachnida. 1. Organs of the mouth in the Scorpion, on one side ; *m*. Mandibles (antennæ), converted into chelæ, and called the chelieeræ ; *p*. Maxillary palpi greatly developed, and forming strong chelæ. 2. Telson of the Scorpion. 3. One of the abdominal segments of the Scorpion, showing the 'stigmata' or apertures of the pulmonary sacs. 4. *Tegenaria domestica*, the common Spider (Male), viewed from below ; *s*. Spinnerets ; *m*. Mandibles with their perforated hooks ; below the mandibles are the maxillæ, and between the bases of these is the labium ; *p*. The maxillary palpi with their enlarged tumid extremities.

converted into prehensile and offensive weapons ; whilst in the Scorpions, as in the King Crabs, they are developed into nipping claws, or chelæ.

In the lower *Arachnida*, the organs of the mouth, though essentially the same as in the higher forms, are enveloped in a sheath, formed by the labium and maxillæ, whilst the mandibles are often joined together so as to constitute a species of lancet.

The mouth opens into a pharynx, which is of remarkably small calibre in the true Spiders, all of which live simply on the juices of their prey. The intestinal canal is usually short and straight, no convolutions intervening between the mouth and the aperture of the anus. Salivary glands are also present, as well as ramified tubes, supposed to perform the functions of a kidney, and to correspond to the 'Malpighian vessels' of Insects.

The circulation in the *Arachnida* is maintained by a dorsal heart, which is situated above the alimentary canal. Usually the heart is greatly elongated, and resembles the 'dorsal vessel' of the *Insecta*. All the *Arachnida* breathe the air directly, and the respiratory function is performed by the general surface of the body (as in the lowest members of the class), or by ramified air-tubes, termed 'tracheæ,' or by distinct pulmonary chambers or sacs; or, lastly, by a combination of tracheæ and pulmonary vesicles. The 'tracheæ' consist of ramified tubes, opening upon the surface of the body by distinct apertures, called 'stigmata,' and branching freely as they penetrate the tissues internally. The walls of the tube are prevented from collapsing by means of a chitinous fibre or filament, which is coiled up into a spiral, and is situated beneath their epithelial lining. The pulmonary sacs are simple involutions of the integument, abundantly supplied with blood; the vascular surface thus formed being increased in area by the development of a number of close-set membranous lamellæ, or vascular plates, which project into the interior of the cavity. Like the tracheæ, the pulmonary sacs communicate with the exterior by minute apertures, or 'stigmata' (*fig.* 57, 3).

The nervous system is of the normal articulate type, but is often much concentrated. In the Spiders there is a cephalic, or 'cerebral,' ganglion, a large thoracic ganglion, and in some instances a small abdominal ganglion. In none of the *Arachnida* are compound eyes present, and in none are the eyes supported upon foot-stalks. The organs of vision, when present, are in the form of from two to eight simple eyes, or 'ocelli.'

In all the *Arachnida*, with the exception of the *Tardigrada*, the sexes are distinct.

The Arachnida may be divided into two great sections or sub-classes, viz. the *Trachearia*, in which respiration is effected by the general surface of the body, or by tracheæ, and there are never more than four ocelli; and the *Pulmonaria*, in which respiration is effected by pulmonary sacs, either alone or combined with tracheæ, and there are six or more eyes.

CHAPTER XXXVII.

DIVISIONS OF THE ARACHNIDA.

DIVISION A. TRACHEARIA.—*Respiration cutaneous, or by tracheæ. Eyes never more than four in number.*

The *Trachearia* comprise three orders, viz. the *Podosomata*, the *Acarina*, or *Monomerosomata*, and the *Adelarthrosomata*.

ORDER I. PODOSOMATA (*Pantopoda*).—The members of this order, sometimes called 'Sea-spiders,' have been placed alternately amongst the *Arachnida* and the *Crustacea*, their true position being rendered doubtful by the fact, that, though marine in their habits, they possess no differentiated respiratory organs. They possess, however, no more than four pairs of legs, and would, therefore, appear to be properly referable to the *Arachnida.* Some of the order, such as *Nymphon*, are found on the sea-coast beneath stones or upon marine plants; whilst others, such as *Pycnogonum*, are believed to be parasitic upon fishes and other marine animals, though this is denied by some. The legs consist of four pairs, sometimes greatly exceeding the body in length, and sometimes containing cæcal prolongations of the digestive cavity for a portion of their length. The mouth is provided with a pair of 'cheliceræ,' or chelate mandibles, and with two well developed maxillary palpi, behind which in the female are a pair of false legs which carry the ova. The abdomen is rudimentary.

ORDER II. ACARINA, or MONOMEROSOMATA.—The members of this order possess an unsegmented abdomen which is fused with the cephalothorax into a single mass. Respiration is effected by tracheæ. Most of the *Acarina* are parasitic, and the most familiar are the Mites and Ticks.

Family 1. *Linguatulina* or *Pentastomida*.—The members of this family are singular vermiform animals, found as parasites in the frontal sinuses and lungs of some Vertebrates. In their adult condition they possess no external organs except two pairs of hooks, representing limbs, placed near the mouth. They thus closely approximate to the *Tæniada*, beside which they have been generally placed. In the young condition, however, they possess four articulated legs, and even in the adult state the characters of the nervous system are higher than those of the *Scolecida*.

Family 2. *Macrobiotidæ* (*Tardigrada* or *Arctisca*).—The 'Sloth-' or 'Bear-animalcules,' which compose this family, are microscopic animals, very much like *Rotifers*, found in damp moss and in the gutters of houses. The nervous system consists of four ganglia, and there is a suctorial mouth, with rudimentary jaws or stilets. The abdomen is undeveloped, and there are four pairs of rudimentary legs. They exhibit no traces of either circulatory or respiratory organs.

Family 3. *Acarida*.—This family includes the Mites, Ticks, and Water-mites, some of which are parasitic, whilst others are free, and some are even aquatic in their habits. The mouth is formed for suction.

In the true *Acari* (*fig.* 58), of which the Cheese-mite may be taken as an example, there are four pairs of legs, adapted for walking. In the *Sarcoptes scabiei*—the cause of the skin-disease known as the 'itch'—the two anterior pairs of legs are provided with suckers, and the two posterior are terminated by bristles; the mouth, also, is furnished with bristles. In the Ticks (*Ixodes*) the mouth is provided with a beak, or 'rostrum,' which enables them to pierce the skin, and retain their hold firmly. In the *Hydrachnidæ*, or Water-mites, the head is furnished with two or four ocelli, and there are four pairs of hairy natatory legs. They are parasitic, during at least a portion of their existence, upon Water-beetles and other aquatic insects. They pass through a metamorphosis, the larva being hexapod, or having only three pairs of legs.

Fig. 58.—Acarina. *Tetranychus telarius*, a 'sociable' Mite, much enlarged.

Another member of the *Acarina* is the curious little *Demodex folliculorum*, which is found in the sebaceous follicles of man, especially in the neighbourhood of the nose. It is probable that very few, if any, individuals are exempt from this harmless parasite.

ORDER III. ADELARTHROSOMATA.—The members of this order, comprising the Harvest Spiders, the Book-scorpions, &c. are distinguished from the preceding by the possession of an abdomen, which is more or less distinctly segmented, but generally exhibits no line of separation from the cephalothorax, the two regions being of equal breadth and conjoined together. The mouth is furnished with masticatory appendages, and respiration is effected by tracheæ, which open on the lower surface of the body by two or four stigmata.

Family 1. *Phalangidæ.*—The well known 'Harvest-spiders' belong to this family. They are characterised by the great length of the legs, and by the filiform maxillary palpi, terminated by simple hooks.

Family 2. *Pseudo-scorpionidæ* (Cheliferidæ).—The 'Book-scorpion' (*Chelifer*) is a common little animal in old books. It is distinguished by the fact that the maxillary palpi are of large size, and are converted into nipping-claws, or chelæ, thus giving the animal the appearance of a Scorpion in miniature.

Family 3. *Solpugidæ.*—In this family the abdomen is not only very distinctly segmented, but is also clearly separated from the abdomen. The mandibles in *Galeodes*, which is the type of the group, are chelate, but the maxillary palpi constitute long feet.

DIVISION B. PULMONARIA.—*Respiration by pulmonary sacs alone, or by pulmonary sacs conjoined with tracheæ. Eyes six or more in number. Abdomen usually distinct from the cephalothorax.*

This division comprises the higher *Arachnida*, such as the Scorpions, and the majority of what are commonly known as Spiders; the former constituting the order of the *Pedipalpi*, the latter that of the *Araneida* or *Dimerosomata*.

ORDER I. PEDIPALPI.—In this order are the true Scorpions, together with certain other animals which are in some respects intermediate between the Scorpions and the true Spiders. The members of this order are distinguished by the fact that the abdomen in all is distinctly segmented, but is not separated from the cephalothorax by a well marked constriction. They agree in this character with the *Adelarthrosomata*; hence the two are sometimes united into a single order (*Arthrogastra*), but they are separated by the nature of the respiratory organs, the latter breathing by tracheæ, and not by pulmonary sacs.

Family 1. *Scorpionidæ.*—The Scorpions are amongst the best known of the *Arachnida*, as well as being amongst the largest. They are distinguished by their long, distinctly segmented abdomen, terminating in a hooked claw (*fig.* 57, 2). This claw, which is really a modified 'telson,' is the chief offensive weapon of the Scorpion, and is perforated at its point by the duct of a poison-gland which is situated at its base. The abdomen is composed of twelve somites, but there is no evident line of demarcation between this region and the cephalothorax. The thoracic segments carry four pairs of ambulatory feet. The maxillary palpi are greatly developed, and constitute strong nipping claws, or 'chelæ' (*fig.* 57, 1). The mandibles (antennæ) also form claws, or 'cheliceræ.' The respiratory organs are in the form of pulmonary sacs, four on each side, opening upon the under surface of the abdomen by as many stigmata, each of which is surrounded by a raised margin, or 'peritrema' (*fig.* 57, 3).

The Scorpions are mostly inhabitants of warm regions, and their sting, though much exaggerated, is of a very severe nature.

Family 2. *Thelyphonidæ.*—The members of this family in external appearance closely resemble the true Spiders, from which they are separated by the possession of a segmented abdomen and long, spinose palpi, and by the absence of spinnerets. They are distinguished from the *Scorpionidæ*, by the amalgamation of the head and thorax into a single mass, which is clearly separated from the abdomen by a slight constriction, as well as by the fact that the maxillary palpi terminate in movable claws, instead of chelæ. Further, the extremity of the abdomen is not furnished with a terminal hook, or 'sting.'

ORDER II. ARANEIDA, or DIMEROSOMATA.—This order includes the true Spiders, which are characterised by the amalgamation of the cephalic and thoracic segments into a single mass, and by the generally soft, unsegmented abdomen, attached to the cephalothorax by a constricted portion, or peduncle. Respiration is effected by pulmonary sacs usually in combination with tracheæ. (Hence the name *Pulmotrachearia*, sometimes applied to the order.) The number of the pulmonary sacs is smaller in the true Spiders than in the Scorpions, being either two or four, opening by as many stigmata upon the under surface of the abdomen.

The head bears from six to eight simple eyes; the mandibles are simply hooked, and are perforated by the duct of a gland which secretes a poisonous fluid; and the maxillary palpi are never chelate.

Spiders (*fig.* 59) are all predaceous animals, and many of them possess the power of constructing webs for the capture of their prey or for lining their abodes. For the production of the web, Spiders are furnished with a special gland situated at the extremity of the abdomen. The secretion of this gland is a viscid fluid which hardens rapidly on exposure to air, and which is cast into its proper, thread-like shape, by being passed through what are called the 'spinnerets.' These are little conical or cylindrical organs four or six in number, situated below the extremity of the abdomen. The excretory ducts of the gland open into the spinnerets, each of which has its apex perforated by a great number of minute tubes, through which the secretion of the gland has to pass before reaching the air. Many spiders, however, do not construct any web, unless it be for their own habitations, but hunt their prey for themselves.

As regards the reproductive process in the Spiders, it appears certain that the act of copulation, so to speak, is performed by the males by means of the maxillary palpi, the extremities of which are specially modified for this purpose. The testes are abdominal, but the semen appears to be stored up in the enlarged extremities of the maxillary palps, which thus perform the part of the vesiculæ seminales. 'The most careful observations, repeated by the most attentive and experienced entomologists, have led to the conviction that the ova are fertilised by the alternate introduction into the vulva of the appendages of the two palpi of the male. Treviranus's supposition that these acts are merely preliminary stimuli, has

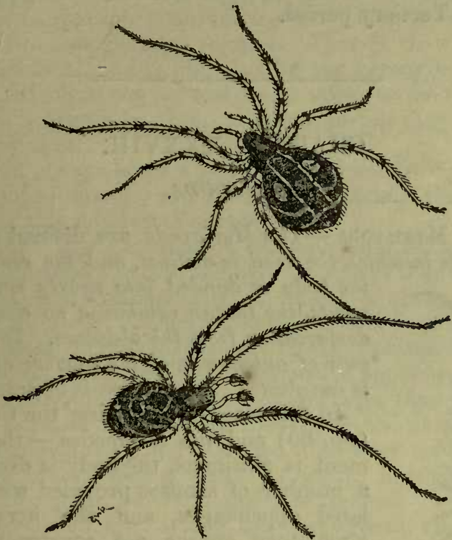


Fig. 59.—Araneida. *Theridion riparium*, male and female, enlarged.

received no confirmation, and is rejected by Dugés, Westwood, and Blackwall; and with good reason, as the detection of the spermatozoa in the palpal vesicles has shown. . . . Dugés offers the very probable suggestion that the male himself may apply the dilated cavities of the palpi to the abdominal aperture (of the testes), and receive from the vasa deferentia the fertilising fluid, preparatory to the union. . . Certain it is that an explanation of this singular condition of the male apparatus, in which the intromittent organ is transferred to the remote and out-stretched palp, is afforded by the insatiable proneness to slay and devour in the females of these most predaceous of articulated animals.'—(Owen.)

The Spiders are oviparous, and the young pass through no metamorphosis; but they cast their skins, or moult, repeatedly, before they attain the size of the adult.

Distribution of Arachnida in Time.—The *Arachnida* are only very rarely found in a fossil condition. As far as is yet known, both the Scorpions and the true Spiders appear to have their commencement in the Carboniferous Epoch, the former being represented by the celebrated *Cyclophthalmus senior* from the Coal-measures of Bohemia. Spiders are, also, known to occur in the Jurassic Rocks (Solenhofen Slates) and in the Tertiary period.

CHAPTER XXXVIII.

MYRIAPODA.

CLASS III. MYRIAPODA.—The *Myriapoda* are defined as *articulate animals in which the head is distinct, and the remainder of the body is divided into nearly similar segments, the thorax exhibiting no clear line of demarcation from the abdomen. There is one pair of antennæ, and the number of the legs is indefinite. Respiration is by tracheæ.*

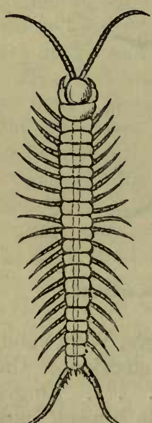


Fig. 60.—Centipede (*Scolopendra*) reduced.

In this class—comprising the Centipedes (*fig.* 60) and the Millipedes — the integument is chitinous, the body is divided into a number of somites provided with articulated appendages, and the nervous and circulatory organs are constructed upon a plan similar to what we have seen in *Crustacea* and *Arachnida*. The head is invariably distinct, and there is no marked line of demarcation between the segments of the thorax and those of the abdomen. The body always consists of more than twenty somites, and those which correspond to the abdomen in the *Arachnida* and *Insecta* are always provided with locomotive limbs. 'The head consists of at least five, and probably of six, coalescent and modified somites, and some of the anterior segments of the body are, in many genera, coalescent, and have their appendages specially modified to subserve prehension.'—(Huxley.)

The respiratory organs agree with those of the *Insecta* and of many of the *Arachnida* in being 'tracheæ,' that is to say, ramified tubes, which open upon the surface of the body by minute apertures, or 'stigmata,' and the walls of which are strengthened by a spirally coiled filament of chitine.

The somites, with the exception of the head and the last abdominal segment, are usually undistinguishable from one another, and each bears a single pair of limbs. In some cases, however, each segment appears to be provided with two pairs of appendages. This is really due to the coalescence of the somites in pairs, each apparent segment being in reality composed of two amalgamated somites. This is shown, not only by the bigeminal limbs, but also by the arrangement of the stigmata, which in the normal forms occur on every alternate ring only, whereas in these aberrant forms they are found upon every ring.

The head always bears a pair of jointed antennæ, resembling those of many Insects, and behind the antennæ there is generally a variable number of simple eyes.

The young, in some cases, on escaping from the egg, possess nearly all the characters of the parents, except that the number of somites, and consequently of limbs, is always less, and increases at every change of skin ('moult' or 'ecdysis'). In other cases, there is a species of metamorphosis, the embryo being at first either devoid of locomotive appendages, or possessed of no more than three pairs of legs, thus resembling the true hexapod Insects. In these cases the number of legs proper to the adult is not obtained until after several moults, the entire process being stated to occupy in some species as much as two years, before maturity is reached.

The *Myriapoda* are divided into two orders, viz. the *Chilopoda* and the *Chilognatha*.

ORDER I. CHILOPODA.—This order comprises the well-known Centipedes and their allies, and is characterised by the number of legs being rarely indefinitely great (usually from 15 to 20 pairs), by the composition of the antennæ out of not less than 14 joints (14 to 40 or more), and by the structure of the masticating organs. These consist of a pair of mandibles with small palpi, a labium, and two pairs of 'maxillipedes,' or foot-jaws, of which the second is hooked, and is perforated for the discharge of a poisonous fluid. There is not more than one pair of legs to each somite, and the last two limbs are often directed backwards in the axis of the body, so as to form a kind of tail.

Scolopendra (*fig.* 60), *Lithobius*, and *Geophilus* are common European genera of this order. The ordinary Centipedes of this country are perfectly harmless, but those of tropical regions sometimes attain a length of a foot, or more, and these are capable of inflicting very severe, and even dangerous, bites.

ORDER II. CHILOGNATHA.—This order comprises the Millipedes (*Iulidæ*) and the Gallyworms (*Polydesmus*). The order is characterised by the great number of legs, each segment—

except the anterior ones—bearing two pairs; by the composition of the antennæ out of six or seven joints; and by the structure of the masticating organs, which consist of a pair of mandibles without palps, covered by a lower lip, composed of the confluent maxillæ.

In the common Millipede (*Iulus*) the body is composed of from forty to fifty segments, each of which bears two pairs of minute, thread-like legs. The *Iuli* of this country are of small size, but an American species attains a length of more than half a foot.

DISTRIBUTION OF MYRIAPODA IN TIME.—About twenty species of *Myriapoda* are known as fossils, the oldest example of the order having been found in the Carboniferous Epoch. From rocks of this age several species of Chilognathous Myriapods have been discovered. They belong to the genera *Xylobius* and *Archiulus*, and have been placed in a special family under the name of *Archiulidæ*. The occurrence of air-breathing articulate animals (both *Arachnida* and *Myriapoda*) in the Carboniferous period is noticeable, as being cotemporaneous with the earliest known terrestrial Molluscs.

CHAPTER XXXIX.

INSECTA.

GENERAL CHARACTERS OF THE INSECTA.

CLASS IV. INSECTA.—The *Insecta* are defined as *articulate animals in which the head, thorax, and abdomen are distinct; there are three pairs of legs borne on the thorax; the abdomen is destitute of legs; a single pair of antennæ is present; mostly, there are two pairs of wings on the thorax. Respiration is effected by tracheæ.*

In the *Insecta* the body is divided into a variable number of definite segments, or somites, some of which are furnished with jointed appendages, and the nervous and circulatory systems are constructed upon essentially the same plan as in the *Crustacea*, *Arachnida* and *Myriapoda*. The head, thorax, and abdomen are distinct (*fig.* 61), and the total number of somites in the body never exceeds twenty. 'Of these, five certainly, and six probably, constitute the head, which possesses a pair of antennæ, a pair of mandibles, and two pairs of maxillæ, the hinder pair of which are coalescent, and form the "labium." Three, or perhaps, in some cases, more, somites unite and become specially modified to form the thorax, to which the three pairs of locomotive limbs, characteristic of perfect Insects, are attached. Two additional pairs of locomotive organs, the wings, are developed, in most insects, from the tergal walls of the second and third thoracic somites. No locomotive limbs are ever developed from the abdomen of

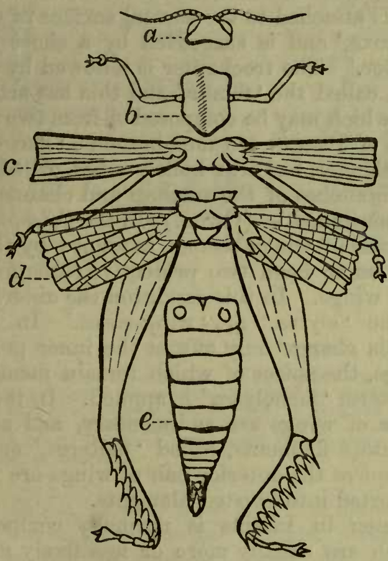


Fig. 61.—Diagram of Insect. *a*. Head, carrying the eyes and antennæ; *b*. Prothorax, carrying the first pair of legs; *c*. Mesothorax, carrying the second pair of legs and first pair of wings; *d*. Metathorax, with the third pair of legs and the second pair of wings; *e*. Abdomen, without limbs, but having terminal appendages subservient to reproduction.

the adult insect, but the ventral portions of the abdominal somites, from the eighth backwards, are often metamorphosed into apparatuses ancillary to the generative function.'—(Huxley.)

The integument of the *Insecta*, in the mature condition, is more or less hardened by the deposition of chitine, and usually forms a resisting exoskeleton, to which the muscles are attached. The segments of the head are amalgamated into a single piece, which bears a pair of jointed feelers, or antennæ, a pair of eyes, usually compound, and the appendages of the mouth. The segments of the thorax are also amalgamated into a single piece; but this, nevertheless, admits of separation into its constituent three somites (*fig.* 61). These are termed respectively, from before backwards, the 'prothorax,' 'mesothorax,' and 'metathorax,' and each bears a pair of jointed legs. In the great majority of Insects, the dorsal arches of the mesothorax and metathorax give origin, each, to a pair of wings.

Each leg consists of from six to nine joints. The first of these, which is attached to the sternal surface of the thorax, is called the 'coxa,' and is succeeded by a short joint, termed the 'trochanter.' The trochanter is followed by a joint, often of large size, called the 'femur,' and this has articulated to it the 'tarsus,' which may be composed of from two to five joints.

The wings of Insects are membranous, 'flattened vesicles, sustained by slender, but firm, hollow tubes, called "nervures," along which branches of the tracheæ and channels of the circulation are continued.'—(Owen.) In the *Coleoptera* (Beetles) the anterior pair of wings become hardened by the deposition of chitine, so as to form two protective cases for the hinder membranous wings. In this condition the anterior wings are known as the 'elytra,' or 'wing-cases.' In some of the *Hemiptera* this change only affects the inner portions of the anterior wings, the apices of which remain membranous, and to these the term 'hemelytra' is applied. In the *Diptera* the posterior pair of wings are rudimentary, and are converted into two capitate filaments, called 'halteres,' or 'balancers.' In the *Strepsiptera* the anterior pair of wings are rudimentary, and are converted into twisted filaments.

The abdomen in Insects is normally composed of nine somites, which are usually more or less freely movable upon one another, and never carry locomotive limbs. The extremity of the abdomen is, however, not infrequently furnished with appendages, which are connected with the generative function, and not infrequently serve as offensive and defensive weapons. Of this nature are the ovipositors of Ichneumons and other Insects, and the sting of Bees and Wasps. In the Earwig (*Forficula*) these caudal appendages form a pair of forceps, whilst in many Insects they are in the form of bristles, by which powerful leaps can be effected, as is seen in the Springtails (*Poduræ*).

The organs about the mouth in Insects are collectively termed the 'trophi,' or 'instrumenta cibaria.' Two principal types require consideration, namely, the masticatory and the suctorial, both types being sometimes modified, and occasionally combined.

In the Masticatory Insects, such as the Beetles (*fig.* 62, 1), the trophi consist of the following parts, from before backwards:—(1) An upper lip, or 'labrum,' attached below the front of the head. (2) A pair of biting jaws, or 'mandibles.' (3) A pair of chewing jaws, or 'maxillæ,' provided with one or more pairs of 'maxillary palps,' or sensory and tactile filaments. (4) A lower lip, or 'labium,' composed of a second coalescent pair of maxillæ, and also bearing a pair

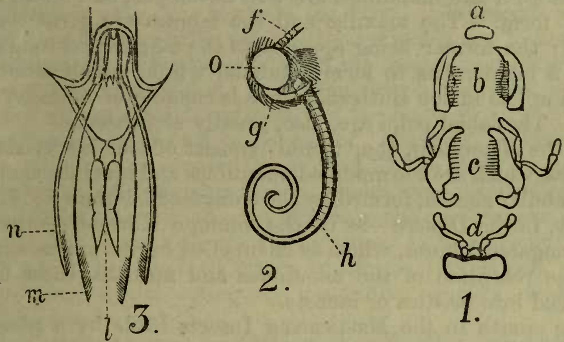


Fig. 62.—Organs of the mouth in Insects. 1. Trophi of a masticating Insect (Beetle); *a.* Labrum or upper lip; *b.* Mandibles; *c.* Maxillæ with their palpi; *d.* Labium or lower lip with its palpi. 2. Mouth of a Butterfly; *o.* Eye; *f.* Base of antenna; *g.* Labial palp; *h.* Spiral trunk or 'antlia.' 3. Mouth of a Hemipterous insect (*Nepa cinerea*); *l.* Labium; *m.* Maxillæ; *n.* Mandibles.

of palpi, the 'labial palps.' The lower or basal portion of the labium is called the 'mentum' or chin, whilst the upper portion is more flexible, and is termed the 'ligula.' The upper portion of the ligula is often developed into a kind of tongue, which is very distinct in some Insects, and is termed the 'lingua.'

In the typical suctorial mouth, as seen in the Butterflies (*fig.* 62, 2), the following is the arrangement of parts. The labrum and the mandibles are now quite rudimentary; the first pair of maxillæ is greatly elongated, each maxilla forming a half-tube. These maxillæ adhere together by their inner surfaces, and thus form a spiral 'trunk,' or 'antlia' (inappropriately called the 'proboscis'), by which the juices of flowers are sucked up. Each maxilla, besides the half-tube on one side, contains also a tube in its interior; consequently on a transverse section the trunk is found really to consist of three canals, one in the interior of each maxilla, and the third formed between them by their apposition. To the base of the trunk are attached the maxillary palpi, which are extremely small. Behind the trunk is a small labium, composed of the united second pair of maxillæ. The 'labial palpi' are greatly developed, and form two hairy cushions, between which the trunk is coiled up, when not in use.

In the Bee there exists an intermediate condition of parts, the mouth being fitted partly for biting and partly for suction. The labrum and mandibles are well developed, and retain their usual form. The maxillæ and the labium are greatly elongated; the former being apposed to the lengthened tongue in such a manner, as to form a tubular trunk, which cannot be rolled up, as in the Butterflies, but is capable of efficient suction. The labial palpi are, also, greatly elongated.

In the *Hemiptera*, the 'trophi' consist of four lancet-shaped needles, which are the modified mandibles and maxillæ, enclosed in a tubular sheath, formed by the elongated labium (*fig.* 62, 3). Lastly, in the *Diptera*—as in the common House-fly—there is an elongated labium, which is channelled on its upper surface for the reception of the mandibles and maxillæ, these being modified into bristles or lancets.

The mouth in the Masticating Insects leads by a pharynx and œsophagus into a membranous, usually folded, stomach —the 'crop,' or 'ingluvies'—from which the food is transmitted to a second muscular stomach, called the 'gizzard.' The gizzard is adapted for crushing the food, often having plates or teeth of chitine developed in its walls, and is succeeded by the true digestive cavity, called the 'chylific stomach' (*ventriculus chylopoieticus*). From this an intestine of variable length proceeds, its terminal portion, or rectum, opening into a dilatation which is common to the ducts of the generative organs, and is termed the 'cloaca.' The œsophagus is usually furnished with salivary glands, and is provided in some of the Suctorial Insects with a dilatation, called the 'sucking stomach.' Behind the pyloric aperture of the stomach are a variable number of cæcal, convoluted tubes, which open into the intestine, and are called the 'Malpighian tubes.' These are usually looked upon as representing the liver, but are by some believed to have a renal function. If the Malpighian vessels truly perform the functions of a liver—as their position would appear to prove—then the kidneys will be represented by a series of cæcal tubes which open into the rectum, close to the cloaca. There are no absorbent vessels, and the products of digestion simply transude through the walls of the alimentary canal into the sinuses, or irregular cavities, which exist between the abdominal organs. The apparatus of digestion does not differ essentially from the above in any of the Insects, but the alimentary canal is, generally speaking, considerably lengthened in the herbivorous species.

There is no definite and regular course of the circulation in the Insects. The propulsive organ of the circulation is a long contractile cavity, situated in the back and termed the 'dorsal vessel.' This is composed of a number of sacs, opening into one another by valvular apertures, which allow of a current in one direction only, viz. towards the head. The blood is collected from the irregular venous sinuses which are formed by the lacunæ and interstices between the tissues, and enters the dorsal vessel from behind; it is then driven forwards, and is expelled at the anterior extremity of the body.

Respiration is effected by means of 'tracheæ,' or branched tubes, which commence at the surface of the body by lateral apertures, called 'stigmata,' or 'spiracles,' and ramify through every part of the animal. In structure the tracheæ are membranous, but their walls are strengthened by a chitinous filament, which is rolled up into a continuous spiral coil. The wings, also, whilst acting as locomotive organs, doubtless subserve respiration.

The nervous system in Insects, though often concentrated into special masses, consists essentially of a chain of ganglia, placed ventrally, and united together by a series of double cords or commissures. The cephalic, or 'præ-œsophageal,' ganglia are of large size, and distribute filaments to the eyes and antennæ. The post-œsophageal ganglia are united to the preceding by cords which form a collar round the gullet, and they supply the nerves to the mouth, whilst the next three ganglia furnish the nerves to the legs and wings.

The organs of sense are the eyes and antennæ. The eyes in Insects are usually 'compound,' and are composed of a number of hexagonal lenses, united together, and each supplied with a separate nervous filament. Besides these, simple eyes —'ocelli,' or 'stemmata'—are sometimes present, or, in rare cases, may be the sole organs of vision. In structure these resemble the single elements of the compound eyes. The antennæ are movable, jointed filaments, attached usually close to the eyes, and varying much in shape in different Insects. They doubtless discharge the functions of tactile organs, but are probably the organ of other more recondite senses in addition.

The sexes in Insects are in different individuals, and most are oviparous. Generally speaking, the young insect is very different in external characters from the adult, and it requires to pass through a series of changes, which constitute the 'metamorphosis,' before attaining maturity. In some Insects, however, there appears to be no metamorphosis, and in some the changes which take place are not so striking or so complete as in others. By the absence of metamorphosis or by the degree of its completeness, when present, Insects are divided into sections, called respectively *Ametabola*, *Hemimetabola*, and *Holometabola*, which, though not, perhaps, of a very high scientific value, are, nevertheless, very convenient in practice.

Section 1. *Ametabolic Insects.*—These pass through no metamorphosis, and, also, in the mature condition, are destitute of wings. The young of these insects (*Aptera*) on escaping from the ovum resemble their parents in all respects except in size; and though they may change their skins frequently, they undergo no alteration before reaching the perfect condition, except that they grow larger.

Section 2. *Hemimetabolic Insects.*—In the insects belonging to this section there is a metamorphosis consisting of three stages. The young on escaping from the ovum is termed the 'larva;' when it reaches its second stage it is called the 'pupa,' or 'nymph;' and in its third stage, as a perfect insect, it is called the 'imago.' In the *Hemimetabola* the 'larva,' though, of course, much smaller than the adult, or 'imago,' differs from it in little else except in the absence of wings. It is active and locomotive, and is generally very like the adult in external appearance. The 'pupa,' again, is a little larger than the larva, but really differs from it in nothing else than in the fact that the rudiments of wings have now appeared, in the form of lobes enclosed in cases. The 'pupa' is still active and locomotive, and the term 'nymph' is usually applied to it. The pupa is converted into the perfect insect, or 'imago,' by the liberation of the wings, no other change being requisite for this purpose. From the comparatively small amount of difference between these three stages, and from the active condition of the pupa, this kind of metamorphosis is said to be 'incomplete.'

In some members of this section, however—such as the Dragon-flies—the larva and pupa are aquatic, whereas the imago leads an aërial life. In these cases, there is necessarily a considerable difference between the larva and the adult; but the larva and pupa are closely alike, and the latter is active.

Section 3. *Holometabolic Insects.*—These—comprising the Butterflies, Moths, Beetles, &c.—pass through three stages which differ greatly from one another in appearance, the metamorphosis, therefore, being said to be 'complete.' In these insects (*fig.* 68) the 'larva' is vermiform, segmented, and usually provided with locomotive feet, which do not correspond with those of the adult, though these latter are usually present as well. In some cases the larva is destitute of legs, or is 'apodal.' The larva is also provided with masticatory organs, and usually eats voraciously. In this stage of the metamorphosis the larvæ constitute what are usually called 'caterpillars' and 'grubs.' Having remained in this condition for a longer or shorter length of time, and having undergone repeated changes of skin, or 'moults,' necessitated by its rapid growth, the larva passes into the second stage, and becomes a 'pupa.' The insect is now perfectly quiescent, unless touched or otherwise irritated, is incapable of changing its place, and is often attached to some foreign object. This constitutes what —in the case of the *Lepidoptera* — is generally known as the 'chrysalis,' or 'aurelia.' The body of the pupa is usually covered by a chitinous pellicle, which closely invests the animal. In some cases the pupa is further protected within the dried skin of the larva; and in other cases the larva—immediately before entering upon the pupa-stage—spins, by means of special organs for the purpose, a protective case, which surrounds the chrysalis, and is termed the 'cocoon' (*fig.* 68).

Having remained for a variable time in the quiescent pupa-stage, and having undergone the necessary development, the insect now frees itself from the envelope which obscured it, and appears as the perfect adult, or 'imago,' characterised by the possession of wings.

Sexes of Insects.—The great majority of Insects, as is the case with most of the higher animals, consist of male and female individuals; but there occur some striking exceptions to this rule, as seen in the Social Insects. In those organised communities which are formed by Bees, Ants, and Termites, by far the greater number of the individuals which compose the colony are either undeveloped females, or are of no fully developed sex. This is the case with the workers amongst Bees, and the workers and soldiers amongst Ants and Termites. And these sterile individuals, or 'neuters,' as they are commonly called, are not necessarily all alike in structure and external appearance. Amongst the Bees all the neuters resemble one another, but amongst Ants and Termites they are often divided into 'castes,' which have different functions to perform in the general polity, and differ from one another greatly in their characters.

In all the above-mentioned insects, the males are relieved from the performance of any of the duties of life, except that of propagating the species; and the females—which are generally solitary in each community—fulfil no other function save that of laying eggs. All the other duties which are necessary for the existence of the community are performed by the workers, or neuters.

CHAPTER XL.

DIVISIONS OF INSECTA.

The class *Insecta* includes such an enormous number of species, genera, and families, that it would be impossible to treat of these satisfactorily, otherwise than in a treatise especially devoted to Entomology. Here it will be sufficient to give simply the differential characters of the different orders, drawing attention occasionally to any of the more important points in connection with any given family.

As already said, the *Insecta* are divided into three divisions, termed *Ametabola*, *Hemimetabola*, and *Holometabola*, according as they attain the adult condition without passing through a metamorphosis, or have an incomplete or complete metamorphosis. The Insects which come under the first head (viz. *Ametabola*) are not furnished with wings in the adult condition, and the three orders which compose this section are commonly grouped together under the name *Aptera*. By some, however, this division is entirely rejected, and the three orders in question are placed amongst the *Hemimetabola*, or even grouped with the *Myriapoda*.

Sub-class I. Ametabola. — *Young not passing through a metamorphosis, and differing from the adult in size only. Imago destitute of wings; eyes simple, sometimes wanting.*

Order I. Anoplura.—Minute *Aptera*, in which the mouth is formed for suction; and there are two simple eyes, or none.

This order comprises insects which are commonly parasitic upon man and other animals, and are known as Lice (*Pediculi*). The common Louse is furnished with a simple eye, or ocellus, on each side of a distinctly differentiated head, the under surface of which bears a suctorial mouth. There is little distinction between the thorax and abdomen, but the segments of the former carry three pairs of legs. The young pass through no metamorphosis, and their multiplication is extremely rapid.

Order II. Mallophaga.—Minute *Aptera*, in which the mouth is formed for biting, and is furnished with mandibles and maxillæ.

The members of this order are cemmonly known as 'Bird-lice,' being parasitic, sometimes upon Mammals, but mostly upon Birds. They strongly resemble the *Pediculi*, but the mouth is formed for biting, to suit their mode of life; since they do not live upon the juices of their hosts, but upon the more delicate tegumentary appendages.

Order III. Thysanura.—*Apterous* insects, usually with a masticatory mouth, and having the extremity of the abdomen furnished with locomotive appendages.

The most familiar members of this order are the *Poduræ*, or

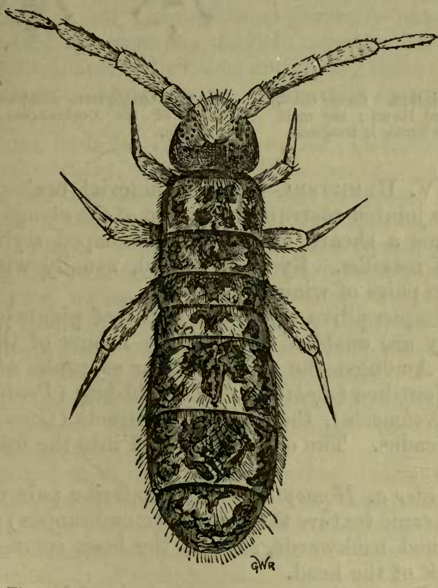


Fig. 63.—Thysanura. *Podura*, without scales, enlarged.

'Spring-tails' (*fig.* 63), which are characterised by the possession of a forked caudal appendage, by the extension of which considerable leaps can be effected. In the nearly allied *Lepismæ* locomotion is assisted by caudal bristles. In both, the body is covered with hairs or scales, the structure of the latter being often very beautiful.

Sub-class II. Hemimetabola.—*Metamorphosis incomplete;*

*the larva differing from the imago chiefly in the absence of wings, and in size; pupa usually active, or, if quiescent, capable of movement.**

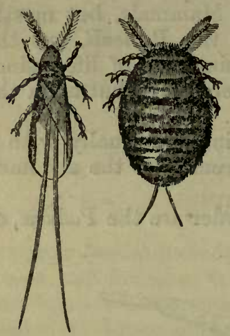


Fig. 64.—Hemiptera. *Coccus Cacti,* the Cochineal Insect; the male is winged, the female is wingless.

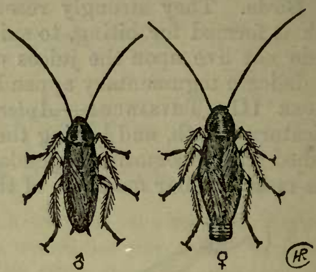


Fig. 65.—Orthoptera. *Ectobius Germanica,* one of the Cockroaches, male and female.

Order IV. Hemiptera.—Mouth suctorial, beak-shaped, consisting of a jointed rostrum, composed of the elongated labium, which forms a sheath for the bristle-shaped styliform mandibles and maxillæ. Eyes compound, usually with ocelli as well. Two pairs of wings.

The *Hemiptera* live upon the juices of plants or animals, which they are enabled to obtain by means of the suctorial rostrum. Amongst the more familiar examples of this order are the Plant-lice (*Aphides*), the Field-bug (*Pentatoma*), the Boat-fly (*Notonecta*), the Cochineal Insects (*Cocci*) (*fig.* 64), and the Cicadas. The order is divided into the following two sub-orders:—

Sub-order a. Homoptera.—The anterior pair of wings of the same texture throughout (membranous); the mouth turned backwards, so that the beak springs from the back of the head.

Sub-order b. Heteroptera.—Anterior wings membranous near their apices, but chitinous towards the base (hemelytra). The rostrum springing from the front of the head.

Order V. Orthoptera.—Mouth masticatory; wings four; the anterior pair smaller than the posterior, coriaceous or lea-

* The *Coccidæ,* amongst the *Hemiptera,* undergo a complete metamorphosis.

thery, and forming elytra; posterior pair of wings membranous, folded longitudinally like a fan.

This order includes the Crickets (*Achetina*), Grasshoppers (*Gryllina*), Locusts (*Locustina*), Cockroaches (*Blattina*) (*fig.* 65), &c. Some of them are formed for running (*cursorial*), all the legs being nearly equal in size; whilst in others the first pair of legs are greatly developed, and form powerful raptorial organs, as in the *Mantis*. In others, again, as in the Grasshoppers and Crickets, the hindmost pair of legs are greatly elongated, so as to give a considerable power of leaping to them. All the *Orthoptera* are extremely voracious, and the ravages caused by locusts in hot countries are well known to all.

ORDER VI. NEUROPTERA.—Mouth usually masticatory; wings four in number, all membranous, generally nearly equal in size, traversed by numerous, delicate nervures, having a longitudinal and transverse direction, and giving them a reticulated, lace-like aspect. Metamorphosis generally incomplete, rarely complete.

This order includes the Dragon-flies (*Libellulidæ*), Caddis-flies (*Phryganeidæ*), May-flies (*Ephemeridæ*),* the Ant-lion (*Myrmeleo*), Termites, &c. The last of these, namely, the Termites or White Ants, are social, and live in communities, and their habits are so singular that a short description of them will not be out of place here. They are mostly inhabitants of hot countries, where they are commonly known as 'White Ants,' but it must be borne in mind, that they have nothing to do with the insects commonly called Ants, which belong, indeed, to a different order (*Hymenoptera*). The following account is taken from Mr. Bates's work on the Amazons, where there is an excellent description of the habits of these remarkable insects.

Termites are small, soft-bodied insects, which live in large communities, as do the true Ants. They differ, however, from the Ants in the fact that the workers are individuals of no fully developed sex, whereas amongst the latter they are undeveloped females. Further, the neuters of the Termites are always composed of two distinct classes or 'castes:'—the workers and the soldiers. Lastly, the Ants undergo a quiescent pupa-stage, whereas the young Termites on their emergence from the egg do not differ from the adult in any respect except in size.

* By Huxley the Dragon-flies (*Libellulidæ*), the May-flies (*Ephemeridæ*), and the Termites are placed amongst the *Orthoptera*; whilst the Caddis-Flies are placed in a separate order under the name of *Trichoptera*.

Each species of Termites consists of several distinct orders, or castes, which live together, and constitute populous, organised communities. They inhabit structures, known as 'Termitaria,' consisting of mounds or hillocks, some of which are 'five feet high, and are formed of particles of earth, worked into a material as hard as stone.' The Termitarium has no external aperture for ingress or egress, as far as can be seen, the entrance being placed at some distance, and connected with the central building by means of covered ways and galleries. Each Termitarium is composed of 'a vast number of chambers and irregular intercommunicating galleries, built up with particles of earth or vegetable matter, cemented together with the saliva of the insects.' Many of 'the very large hillocks are the work of many distinct species, each of which uses materials differently compacted, and keeps to its own portion of the tumulus.'

A family of Termites consists of a king and queen, of the workers, and of the soldiers. The royal couple are the parents of the colony, and 'are always kept together, closely guarded by a detachment of workers, in a large chamber in the very heart of the hive, surrounded by much stronger walls than the other cells. They are both wingless, and immensely larger than the workers and soldiers. The queen, when in her chamber, is always found in a gravid condition, her abdomen enormously distended with eggs, which as fast as they come forth, are conveyed by a relay of workers in their mouths from the royal chamber to the minor cells dispersed through the hive.'

At the beginning of the rainy season a number of *winged* males and females are produced, which, when they arrive at maturity, leave the hive, and fly abroad. They then shed their wings (a special provision for this existing in a natural seam running across the root of the wing and dividing the nervures); they pair, and then become the kings and queens of future colonies.

The workers and the soldiers are distinct from the moment of their emergence from the egg, and they do not acquire their special characteristics in consequence of any difference of food or treatment. Both are wingless, and they differ solely in the armature of the head. The duties of the workers are to 'build, make covered roads, nurse the young brood from the egg upwards, take care of the king and queen, who are the progenitors of the whole colony, and secure the exit of the males and females, when they acquire wings, and fly out to pair and disseminate the race.' The duties of the soldiers are to defend the community from all attacks which may be made upon its peace, for which purpose the mandibles are greatly developed.

It may well be admitted, that in such organised communities as those of the Termites, we have the highest development of Insect-life yet known to us. The principle of the division of labour is carried out to its fullest extent—much further, indeed, than is possible amongst human beings—since the perfection of the greater number of the individuals which compose the community—as organisms—is sacrificed in order to secure the fulfilment of the duties which are necessary for the existence and welfare of the whole. Even the task of perpetuating the species and of giving origin to fresh colonies is entirely left to one class of the community, the defence and protection of which is the special object and care of the remainder. No higher development could well be imagined amongst creatures devoid of the higher psychical endowments, and it is worthy of note that at least three distinct and independent families of Insects have attained to this stage, namely, the Termites, the Bees, and the true Ants.

SUB-CLASS III. HOLOMETABOLA.—*Metamorphosis complete; the larva, pupa, and imago differing greatly from one another in external appearance. The larva vermiform, and the pupa quiescent.*

ORDER VII. APHANIPTERA.—Wings rudimentary, in the form of plates, situated on the mesothorax and metathorax. Mouth suctorial. Metamorphosis complete.

This order comprises the Fleas (*Pulicidæ*), most of which are parasitic upon different animals. The larva of the com-

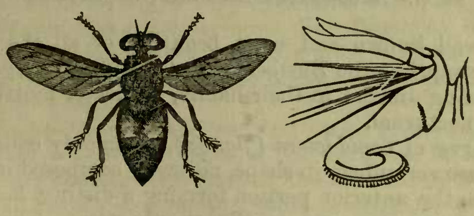
1  2

Fig. 66.—Diptera. 1. *Tabanus cinctus*, the belted Breeze-fly. 2. The organs of the mouth magnified.

mon Flea is an apodal grub, which in about twelve days spins a cocoon for itself, and becomes a quiescent pupa, from which the imago emerges in about a fortnight more.

ORDER VIII. DIPTERA.—The anterior pair of wings alone developed; the posterior pair of wings rudimentary, represented by a pair of clubbed filaments, called 'halteres,' or 'balancers.' Mouth suctorial.

The *Diptera* constitute one of the largest of the orders of the *Insecta*; the House-flies (*Musca*), Gnats (*Culex*), Forest-flies (*Hippobosca*), and Gad-flies (*Tabanidæ*, *fig.* 66), constituting good examples.

ORDER IX. LEPIDOPTERA.—Mouth suctorial, consisting of a spiral trunk or 'antlia,' composed of the greatly elongated maxillæ, protected, when not in use, by the cushion-shaped, hairy labial palpi. Labrum and mandibles rudimentary. Wings four in number, flattened, covered with modified hairs or scales. Larvæ vermiform, commonly known as 'caterpillars.'

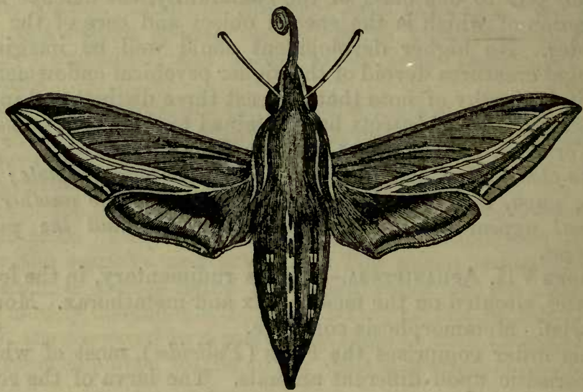


Fig. 67.—The Silver-striped Hawk-moth (*Chærocampa celerio*).

This well known and most beautiful of all the orders of Insects comprises the Butterflies and the Moths (*fig.* 67); the former being diurnal in their habits, the latter mostly crepuscular or nocturnal.

The larvæ of *Lepidoptera* (*fig.* 68), commonly called 'caterpillars,' are vermiform in shape, normally composed of thirteen segments, the anterior portion forming a distinct horny head, with antennæ, jaws, and usually simple eyes. The mouth of the caterpillar, unlike that of the perfect insect, is formed for mastication. The labium also is provided with a tubular organ —the 'spinneret'—which communicates with two internal glands, the functions of which are to furnish the silk, whereby the animal constructs its ordinary abode, or spins its cocoon. The three segments behind the head correspond with the prothorax, mesothorax, and metathorax of the perfect insect, and carry three pairs of jointed walking legs. Besides these, a variable number of the segments of the abdomen are provided with soft, fleshy legs, which are called 'pro-legs.'

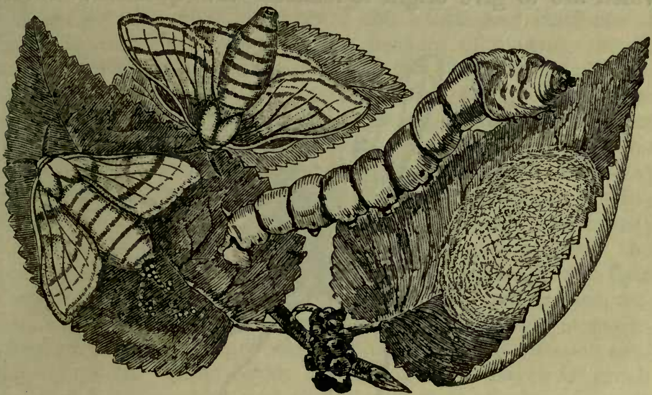


Fig. 68.—The Silk-moth (*Bombyx mori*), showing the three stages of imago, pupa in its cocoon, and larva.

Order X. Hymenoptera.—Wings four, membranous, with few nervures; sometimes absent. Mouth always provided with biting jaws, or mandibles; the maxillæ and labium often converted into a suctorial organ. Females having the extremity of the abdomen mostly furnished with an ovipositor (*terebra* or *aculeus*).

The *Hymenoptera* form a very extensive order, comprising the Bees, Wasps, Ants, Ichneumons, Saw-flies (*fig*. 69), &c. The ovipositor, which is very generally present in the females of this order, is sometimes a boring organ (*terebra*), or in other cases a 'sting' (*aculeus*).

Amongst the *Hymenoptera* we find social communities, in many respects resembling those of the Termites, of which a description has already been given. The societies of Bees and Ants are well known, and merit a short description.

The social Bees, of which the common Honey-bee (*Apis mellifica*), is so familiar an example, form organised communities, consisting of three classes of individuals—the males, females, and neuters. As a rule, each community consists of a single female—the 'queen,' and of the neuters, or 'workers.' The impregnation of the female is effected by the production of males, or 'drones,' during the summer. After impregnation has been effected, the drones, as being then useless, are destroyed by the workers. The eggs produced by the fecundated queen are mostly intended to give origin to neuters, to which end they are placed in the ordinary cells. The ova, which are to give origin to females—the 'queens' of future

Fig. 69.—Hymenoptera. The Great Saw-fly (*Uroceros gigas*).

colonies—are placed in cells of a peculiar construction, and the larvæ are fed by the workers with a special food. The ova, which are to produce males, are likewise placed in cells, which are slightly larger than those allotted to the workers. It is asserted, however, that this is not the sole, or true, cause of the production of the males; but that the ova which are intended to produce drones are not fertilised by the female with the semen which she has stored up in her spermatheca, and are therefore produced by a process of Parthenogenesis. (See Introduction.)

In the Humble Bees (*Bombidæ*), and in the Wasps (*Vespidæ*), we have societies essentially the same as in the Honey-bee.

The Ants (*Formica*) likewise form communities, consisting of males, females, and neuters. The males and females, as we have seen in the case of the Termites, are winged, and are produced in great numbers at a particular period of the year. They then quit the nest and pair, after which the males die. The females then lose their wings, and fall to the ground, when they become the queens of fresh societies. In some Ants—as in the Termites—the neuters are divided into two classes—the workers and the soldiers—of which the former perform all the duties necessary for the preservation of the society, except defending the nest, this being left to the soldiers. In other cases, as many as three distinct orders, or 'castes,' of neuters may be present in the same nest.

Amongst the more singular of the habits and instincts of Ants two may be mentioned—the instinct of making slaves, and that of milking, so to speak, the little Plant-lice (*Aphides*). As regards the first of these, it is found that certain Ants possess the extraordinary instinct of capturing the pupæ of other species of Ants, and bringing them up as slaves. The relations between the masters and the slaves vary a good deal in different species. In the case of *Formica rufescens*, for instance, the masters are entirely dependent upon their slaves; the males and females do nothing except reproducing the species, and the neuters perform no other labour except that of capturing fresh slaves. The masters are, in this case, unable even to feed themselves, and their existence is maintained entirely by the devotion of the slaves. In *Formica sanguinea*, on the other hand, the number of slaves is much less, and both masters and slaves occupy themselves in performing most of the duties necessary for the community. The masters, however, go alone when on slave-making expeditions, and in case of a migration, the masters carry the slaves in their mouths.

A second singular fact in the history of Ants is found in the relations which subsist between them and the *Aphides*, or Plant-lice. The *Aphides* secrete, or rather excrete, a peculiar viscid and sweet liquid, by means of a gland, which is situated towards the extremity of the abdomen, and communicates with the exterior by two tubular filaments. Ants are extremely fond of this excretion, and it is a well established fact that the *Aphides* allow themselves to be *milked*, as it were, by the Ants. For this purpose the Ant touches and caresses the abdomen of the Aphis with its antennæ, whereupon the latter voluntarily exudes a drop of the coveted fluid. Ordinarily the Ants seek the Aphides upon plants, but it is asserted that, in some cases, they *keep* Aphides, much in the same way as human beings keep cows; though this is probably partly imaginary.

ORDER XI. STREPSIPTERA.—Females without wings or feet, parasitic. Males possessing the posterior pair of wings, which are large, membranous, and folded longitudinally like a fan. The anterior pair of wings rudimentary, represented by a pair of singular twisted organs. Jaws abortive.

The *Strepsiptera* constitute a small order, which includes certain parasites of minute size, found on Bees and other *Hymenoptera*. The female is a soft vermiform grub, without feet, but with a horny head, which it protrudes from between the abdominal segments of its host. The larvæ are active, and possess six feet; whilst the males are winged and fly about with great activity.

ORDER XII. COLEOPTERA. — Mouth masticatory, furnished with mandibles and maxillæ. Wings four; anterior pair chitinous, forming protective cases (elytra) for the large, membranous posterior wings (*fig.* 70).

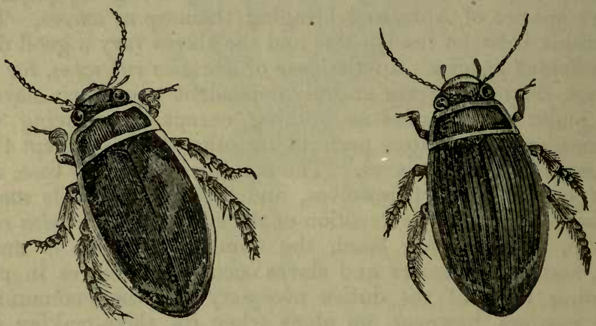


Fig. 70.—Coleoptera. *Dytiscus marginalis*, a common British water-beetle.

The order *Coleoptera* includes all those Insects known commonly as 'Beetles,' comprising an enormous number of species and genera.

The larvæ of the *Coleoptera* are vermiform grubs, with masticatory mouths, usually three pairs of thoracic legs, and often anal pro-legs.

DISTRIBUTION OF INSECTA IN TIME.—The earliest known insects have been discovered in the Devonian Rocks of America, and consist of the remains of *Neuroptera*. Others, as might have been anticipated, have been found in the Coal-measures. In the Secondary Rocks remains of Insects have been found abundantly in certain beds of the Oolitic and Liassic formations. In some Tertiary strata *Lepidoptera* and other insects have been found in a good state of preservation. Amber, which is a fossil resin, has long been known to contain many insects in its interior (in certain specimens); and all of these appear to belong to extinct species, though amber, geologically speaking, is not an ancient product.

MOLLUSCA.

CHAPTER XLI.

SUB-KINGDOM MOLLUSCA.

SUB-KINGDOM MOLLUSCA.—The *Mollusca* may be defined as including soft-bodied animals, which are usually provided with an exoskeleton. The intestinal canal is bounded by its own proper walls, and is completely shut off from the perivisceral cavity. The alimentary canal is situated between the hæmal system, which lies dorsally, and the neural system, which is situated towards the ventral aspect of the body. The nervous system in its highest development consists of three principal ganglia, which are reduced to one in the lower forms. Usually there is a distinct propulsive organ by which the circulation is carried on, but this is occasionally absent. Distinct respiratory organs may, or may not, be present. Reproduction is sexual, though gemmation is, also, occasionally superadded. The higher Mollusca are all simple animals, but many of the lower forms are capable of forming colonies by continuous gemmation.

The digestive system in all the *Mollusca* consists of a mouth, gullet, stomach, intestine, and anus—though in some of the *Brachiopoda* the intestine ends cæcally. In some the mouth is surrounded by ciliated tentacles (*Polyzoa, fig.* 73); in others it is furnished with two ciliated arms (*Brachiopoda, fig.* 75); in the bivalves (*Lamellibranchiata*) it is mostly furnished with four membranous processes or palpi; in others it is provided with a complicated apparatus of teeth (*Gasteropoda, fig.* 77, and *Pteropoda*); and, lastly, the *Cephalopoda* have in addition horny or calcareous mandibles, forming a kind of beak. Well developed salivary glands are usually present; the liver in the higher forms is of large size, and pours its secretion either into the stomach or into the commencement of the intestine; and a renal organ has been detected in most of the *Mollusca* proper. There is no distinct absorbent system, but the products of digestion pass by exosmose into the general abdominal cavity, and thence into the larger veins, which are pierced by numerous round holes for this purpose.

The blood is colourless, or nearly so. In the *Polyzoa* the circulation is carried on by ciliary action, and there is no distinct propulsive organ, or definite course of the circulating fluid. In the *Tunicata*, the heart is a simple tube, open at both ends, and the course of the circulation is periodically reversed. In the *Brachiopoda* the course of the circulation is not definitely ascertained, and it is doubtful if a true heart is present in all. In the higher *Mollusca* a distinct heart is always present, and consists of an auricle which receives the aërated blood from the breathing organ, and a muscular ventricle which propels it through the systemic vessels. That a system of capillaries, in some cases, intervenes between the arteries and veins, appears from recent researches to be probable.

In the *Polyzoa* there is no differentiated respiratory organ, and the function of respiration is discharged mainly by the oral crown of ciliated tentacles. In the *Tunicata* respiration is effected by means of the pharyngeal, or branchial, sac; and in the *Brachiopoda* by the oral arms, and, possibly, to some extent, by an 'atrial' or 'water-vascular' system, furnished with contractile dilatations. In the higher *Mollusca* a distinct breathing organ is always present, a portion of the mantle being specialised for this purpose. In the *Lamellibranchiata*, and the branchiate *Gasteropoda*, the breathing organs are in the form of lamellar and pectinate gills, and the same is the case with the *Cephalopoda*. In the pulmonate *Gasteropoda*, in which respiration is aërial, a pulmonary sac, or air-chamber, is produced by the folding of a portion of the mantle, over the interior of which the pulmonary vessels are distributed. The chamber thus formed communicates with the exterior by a round aperture which can be opened or closed at will; and the renovation of the effete air within the sac appears to be effected mainly, or entirely, by simple diffusion.

The nervous system varies considerably in its development. In the *Polyzoa*, *Tunicata*, and *Brachiopoda*—which collectively constitute the *Molluscoida*—the nervous system consists of a single ganglion, or of a principal pair with accessory ganglia, placed between the oral and anal apertures, or on the ventral surface of the body. The true Molluscan type, however, of nervous system is constituted by the presence of three pairs of ganglia, connected with one another by commissures, but distributed in a characteristically scattered manner (heterogangliate type). One of these ganglia is situated above the œsophagus, and is called the 'supra-œsophageal,' or 'cerebral' ganglion. A second is placed below the œsophagus, and is termed the 'infra-œsophageal,' or 'pedal' ganglion (from its supplying the nerves to the 'foot'). The third pair is the most persistent, and is termed the 'branchial,' or 'parieto-splanchnic' ganglion.

Organs of sight exist in some of the lower, and in the majority of the higher, *Mollusca*. In the *Cephalopoda*, and in some of the *Gasteropoda* (e.g. *Strombidæ*), the eyes are of a very high type of organisation. In the *Lamellibranchiata*, the adults are either destitute of organs of vision, or possess numerous simple eyes ('ocelli') placed along the margins of the mantle-lobes. Similar ocelli are also found in some of the *Tunicata*, placed between the oral tentacles. Organs of hearing exist in the more highly organised *Mollusca*, especially in the *Gasteropoda* and *Cephalopoda*, and supposed olfactory organs occur in some of the latter.

Reproduction amongst the *Mollusca* is almost invariably sexual, but it is by continuous gemmation that the colonies of the *Polyzoa*, and the social and compound *Tunicata*, are produced, and the 'statoblasts' of the former offer a good example of non-sexual reproduction. The sexes are usually distinct, but are in many cases united in the same individual. In many forms, the ova are arranged in rows so as to form a strap- or ribbon-shaped structure, termed the 'nidamental ribbon.'

As implied by their scientific name, the *Mollusca* are mostly soft-bodied animals, but their popular name of 'Shell-fish' expresses the fact, that the presence of a shell, protecting the soft body, is likewise a very characteristic feature in the sub-kingdom. At the same time, a shell is not universally present, and many of the *Mollusca* are either permanently naked, or possess nothing that would be ordinarily looked upon as a shell. When there is either no shell at all, or merely a rudimentary shell enclosed in the mantle, the Mollusc is said to be 'naked.' The shell of the 'testaceous' *Mollusca* is very closely related to the respiratory organs; 'indeed, it may be regarded as a *pneumoskeleton*, being essentially a calcified portion of the mantle, of which the breathing-organ is at most a specialised part. . . . . . In its most reduced form the shell is only a hollow cone, or plate, protecting the breathing-organ and heart, as in *Limax*, *Testacella*, and *Carinaria*. Its peculiar features always relate to the condition of the breathing-organ, and in *Terebratula* and *Pelonaia* it becomes identified with the gill. In the *Nudibranchs* the vascular mantle performs, wholly or in part, the respiratory office. In the *Cephalopods* the shell becomes complicated by the addition of a distinct, internal, chambered portion (*phragmacone*), which is properly a *visceral* skeleton.' —(Woodward.) In a great many of the *Mollusca* proper the shell consists of but a single piece, and they are called 'univalves.' In many others the shell consists of two separate plates, or 'valves,' and these are called 'bivalves.' In others, again, as in the *Chiton*, the shell consists of more than two pieces, and is said to be 'multivalve.' Most, however, of the multivalve shells of older writers are in reality referable to the *Cirripedia*.

All the testaceous *Mollusca* (except the Argonaut), and most of the 'naked' forms, acquire a rudimentary shell before their liberation from the ovum. In the latter this rudimentary shell is cast off as the embryo grows, but in the former it becomes the 'nucleus' of the adult shell. In the bivalves the embryonic shell, or 'nucleus,' is situated at the beak, or 'umbo,' of each valve, and is often very unlike the remainder of the shell.

In composition the shell of the *Mollusca* consists of carbonate of lime—usually having the atomic arrangement of calcite—with a small proportion of animal matter. In the *Pholadidæ*, however, the calcareous matter exists in the allotropic condition of arragonite, which is very much harder than calcite. As regards their texture, three principal varieties of shells may be distinguished, viz. the 'porcellanous,' the 'nacreous,' and the 'fibrous.' In the nacreous or pearly shells, as seen in 'mother-of-pearl,' the shell has a peculiar lustre, due to the minute undulations of the edges of alternate layers of carbonate of lime and membrane. The 'fibrous' shells are composed of successive layers of prismatic cells. The 'porcellanous' shell has a more complicated structure, and is composed of three layers, or strata, each of which is made up of very numerous plates, 'like cards placed on edge.' The direction in which these vertical plates are placed, is sometimes transverse in the central layer, and lengthwise in the two others, or longitudinal in the middle, and transverse in the outer and inner strata.

All living shells have an outer layer of animal matter, which is known as the 'epidermis,' or 'periostracum.' This is sometimes of extreme tenuity, but is sometimes very thick, the latter being especially the case with those shells which are found in fresh water.

In many of the spiral univalves, as the animal grows, it withdraws itself from the upper portion of the shell, often partitioning off the space thus left vacant. In many instances the portion thus abandoned falls off, and the shell becomes 'truncated,' or 'decollated;' this being the normal condition in fully grown examples of some shells.

In the great majority of univalves the shell is coiled into a spiral, the direction of which is right-handed, but in some cases the spiral is left-handed, and the shell is said to be 'reversed,' or 'sinistral.' The reversed shell may occur as the normal condition of the species, or it may occur simply as a variety of a form, which is normally right-handed, or 'dextral.'

The sub-kingdom *Mollusca* is divided into two great divisions, termed respectively the *Molluscoida*, and the *Mollusca* proper. In the former of these the nervous system consists of a single ganglion or principal pair of ganglia, and there is either no circulatory organ or an imperfect heart. In the latter the nervous system consists of three principal pairs of ganglia, and there is a well developed heart, consisting of at least two chambers.

MOLLUSCOIDA.

CHAPTER XLII.

POLYZOA.

DIVISION A. MOLLUSCOIDA.—*Nervous system consisting of a single ganglion, or of a principal pair with accessory ganglia; no distinct organ of the circulation, or an imperfect heart.*

This division includes three classes, viz. the *Polyzoa*, the *Tunicata*, and the *Brachiopoda.*

CLASS I. POLYZOA (*Bryozoa*).—The members of this class are defined as follows:—'Alimentary canal suspended in a double-walled sac, from which it may be partially protruded by a process of evagination, and into which it may be again retracted by invagination. Mouth surrounded by a circle or crescent of hollow, ciliated tentacles; animals always forming composite colonies.'—(Allman.)

All the *Polyzoa* live in an associated form in colonies or 'polyzoaria,' which are sometimes foliaceous (*fig.* 71), sometimes branched and plant-like, sometimes encrusting, and very rarely are free. Each 'polyzoarium' consists of an assemblage of distinct but similar zoöids, arising by continuous gemmation from a single primordial individual. The colonies thus produced are in very many respects closely similar to those of many of the Hydroid Polypes, with which, indeed, the *Polyzoa* were for a long time classed. The 'polyzoarium,' however, of a *Polyzoön* differs from the polypidom of a composite Hydroid in the *general* fact that the separate cells of the former do not communicate with one another otherwise than by the continuity of the external integument; whereas the zoöids of the latter are united by an organic connecting medium, or 'cœnosarc,' from which they take their origin. On this point, Mr. Busk observes:—

'It has been before said that the *Polyzoa* are always associated into compound growths, made up of a congeries of individuals, which though distinct, yet retain some degree of intercommunication, comparable in kind perhaps, though not in degree, to what obtains in many of the compound Ascidians. That this community exists is proved by the otherwise inexplicable circumstance that the polyzoaria in many instances present elements common to the whole growth, and not belonging specially to any individual. The chief bond of connection would appear to reside partly in the continuity of the

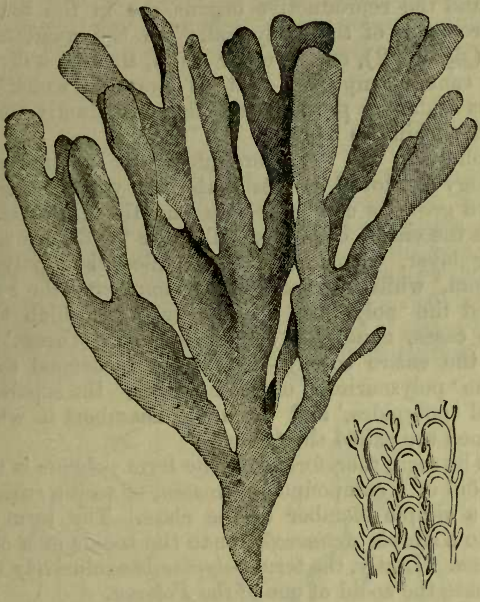


Fig. 71.—Polyzoa. *Flustra hispida*, one of the Sea-mats. 1. Portion of the cœnœcium, natural size. 2. A small fragment enlarged to show the cells.

external integument, and partly also, in all probability, in a slow interchange of the vital fluid with which the cavities of the cells are charged.'

In one sub-order of the *Polyzoa* (*Ctenostomata*), the polyzoarium consists of a series of cells arising from a common tube, but this exception does not affect the value of the above *general* distinction between the *Polyzoa* and the *Hydroida*.

A second point of difference is found in the invariably corneous (or chitinous) texture of the polypidoms of the *Hydroida*, whereas those of the *Polyzoa* may be corneous, or fleshy, but are in the majority of instances more or less highly charged with carbonate of lime.

The homomorphism, however, which subsists between the *Polyzoa* and the *Hydroida* is shown most decisively not to be a true affinity, when the structure of the individual zoöids is examined. The polypite of a hydroid zoophyte, as we have already seen, possesses no alimentary canal distinct from the general cavity of the body; there are no traces of a nervous system, and the reproductive organs are in the form of external processes of the body-wall. In the zoöid of all the *Polyzoa* (*fig.* 72, 2), on the other hand, there is a distinct alimentary canal, completely shut off from the somatic cavity; a nervous system is present, and the reproductive organs are contained within the body.

The following are the more important differences in the terminology employed to designate the various parts of the compound growths of the *Polyzoa* and the *Hydrozoa*. In the *Hydroida* the entire colony is called the 'hydrosoma,' and its investing layer, when present, is called the 'polypary,' or 'polypidom,' whilst the individuals composing the hydrosoma are called the 'polypites,' and the cups in which these are, in some cases, contained are called 'hydrothecæ.' In the *Polyzoa* the entire colony—or its entire dermal system—is called the 'polyzoarium,' or 'cœnœcium;' the separate zoöids are called 'polypides,' and the little chambers in which each is contained are called the 'cells.'

It will be seen, therefore, that the term *polypite* is restricted to the zoöid of a compound *Hydrozoön*, or to the entire hydrosoma of a simple member of the class. The term *polype* is applied to a simple *Actinozoön*, or to the zoöids of a compound actinosoma. Lastly, the term *polypide* is exclusively employed to designate the zoöid of one of the *Polyzoa*.

The construction of a typical polypide of a *Polyzoön* is thus described by Professor Allman (*fig.* 72, 2):—

'Let us imagine an alimentary canal, consisting of œsophagus, stomach, and intestine, to be furnished at its origin with long ciliated tentacula, and to have a single nervous ganglion placed upon one side of the œsophagus. Let us now suppose this canal to be bent back upon itself towards the side of the ganglion, so as to approximate the termination to the origin. Let us further imagine the digestive tube thus constituted to be suspended in a fluid contained in a membranous sac with two openings, one for the mouth, and the other for the vent; the tentacula alone being external to the sac. Let us still further suppose the alimentary tube, by means of a system of muscles, to admit of being retracted or protruded according to the will of the animal; the retraction being accompanied by an invagination of the sac, so as partially or entirely to include the oral tentacles within it; and if to these characters we add the presence of true sexual organs in the form of ovary and testis, occupying some portion of the interior of the sac, and the negative character of the absence of all vestige of a heart, we shall have, perhaps, as correct an idea—apart from all considerations of homology or derivation from an archetype—as can be conveyed of the essential structure of a *Polyzoön* in its simplest and most generalised condition.'

'To give, however, more actuality to our ideal *Polyzoön*, we may bear in mind that the immediately investing sac has the power, in almost every case, of secreting from its external surface a secondary investment of very various constitution in the different groups; and we may, moreover, conceive of the entire animal with its digestive tube, tentacula, ganglion, muscles, generative organs, circumambient fluid, and investing sacs, repeating itself by gemmation, and thus producing one or more precisely similar systems, holding a definite position relatively to one another, while all continue organically united, and we shall then have the actual condition presented by the *Polyzoa* in their fully developed state.'

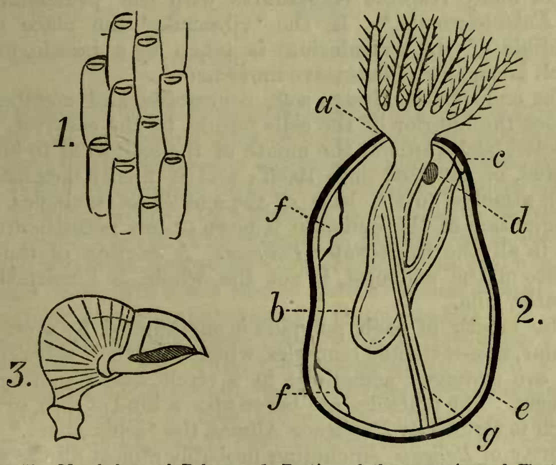


Fig. 72.—Morphology of Polyzoa. 1. Portion of the cœnœcium of *Flustra truncata*, magnified. 2. Diagram of a Polyzoön (after Allman); *a*. Region of the mouth surrounded by tentacles; *b*. Alimentary canal; *c*. Anus; *d*. Nervous ganglion; *e*. Investing sac (ectocyst); *f*. Testis; *f′* Ovary; *g*. Retractor muscle. 3. Bird's-head process, or 'avicularium,' of a Polyzoön.

The vast majority of the *Polyzoa* are fixed, but this is not universally the case. Thus the singular fresh-water *Cristatella* is free and locomotive, creeping about by means of a flattened discoid base, not unlike the foot of the *Gasteropoda*.

The two fundamental structures of the 'cœnœcium' of a

Polyzoön, viz. the immediately investing sac, and its secondary investment, are sometimes termed the 'endoderm' and 'ectoderm,' but as these terms are employed in describing the *Hydrozoa*, it is better to make use of the terms 'endocyst' and 'ectocyst,' proposed by Dr. Allman.

The 'ectocyst,' or external investment of the cœnœcium, is usually a brown, pergamentaceous, probably chitinous, but often highly calcareous, membrane; and it is by the ectocyst that the 'cells' are formed. In *Cristatella*, alone of the *Polyzoa*, there is no ectocyst, and in *Lophopus* the ectocyst is gelatinous in its consistence. In many cases the ectocyst is provided with singular appendages, supposed to be weapons of offence and defence, termed 'avicularia' (*fig.* 72, 3) and 'vibracula.' The avicularia differ a good deal in shape, but consist essentially of 'a movable mandible and a cup furnished with a horny beak, with which the point of the mandible is capable of being brought into apposition.'—(Busk.) In shape the avicularia often closely resemble the head of a bird, and they are in many respects comparable with the 'pedicellariæ' of the *Echinodermata*.* In the 'vibracula,' the place of the mandible of the avicularium is taken by a bristle, or seta, which is capable of extensive movement.

The endocyst is always soft, contractile, and membranous. It lines the interior of the cells formed by the ectocyst, and is reflected backwards at the mouth of the cell, so as to be invaginated, or inverted into itself; and it finally terminates by being attached to the base of the circlet of tentacles. This invagination of the endocyst is more or less permanently present in all the fresh-water *Polyzoa*. A portion of the inner surface of the endocyst, if not the whole, is furnished with vibratile cilia.

The mouth of each polypide is surrounded by a crown of tubular, non-retractile tentacles, which have their sides ciliated, and are arranged sometimes in a circle, and sometimes in a crescent. The tentacles are borne upon a kind of disc, or stage, which is termed by Professor Allman the 'lophophore.' In the majority of *Polyzoa*—including probably almost all the marine species—the lophophore is circular, but in most of the fresh-water forms it has its neural side extended into two long arms, so that the entire lophophore becomes crescentic or 'horse-shoe-shaped' (*fig.* 73); hence this section is sometimes collec-

* There is great reason, however, as shown by Huxley, to regard the *avicularia*, not as mere appendages or organs of any kind, but as peculiarly modified *zoöids*, having many singular points of affinity with the *Brachiopoda*. The *avicularia*, like the *pedicellariæ* of the *Echinodermata*, continue their movements long after the death of the animal.

tively termed the 'Hippocrepian' *Polyzoa*. In all the *Polyzoa* in which this crescentic condition of the lophophore exists, there is also a singular valve-like organ which arches over the mouth, and is termed the 'epistome.'

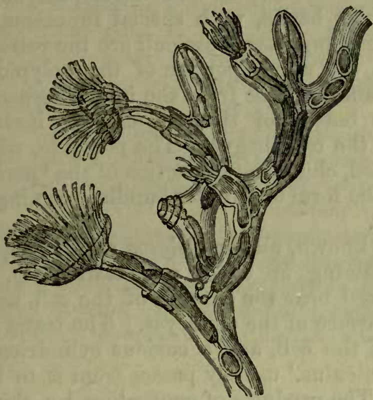


Fig. 73.—*Plumatella repens*, one of the Fresh-water Polyzoa, enlarged. (After Allman.)

The mouth conducts by an œsophagus into a dilated stomach. In some cases a pharynx may be present, and in others there is in front of the stomach a muscular proventriculus, or gizzard. From the stomach proceeds the intestine, which shortly turns forwards to open by a distinct anus close to the mouth. As the nervous ganglion is situated on that side of the mouth, towards which the intestine turns in order to reach its termination, the intestine is said to have a 'neural flexure,' and this relation is constant throughout the entire class.

Respiration in the *Polyzoa* appears to be carried on by the ciliated tentacles, and by the 'perigastric space,' which is filled with a clear fluid, containing solid particles in suspension. A kind of circulation is kept up in this 'perigastric fluid,' by means of the cilia lining the inner surface of the endocyst. Beyond this there is nothing that could be called a circulation, and there are no distinct circulatory organs of any kind.

The nervous system in all the *Polyzoa* consists of a single small ganglion (*fig.* 72, 2), placed upon one side of the œsophagus, between it and the anal aperture. Besides the single ganglion which belongs to each polypide, there is also in many, if not in all of the *Polyzoa*, a 'colonial nervous system.' That is to say, there is a well developed nervous system, which unites together the various zoöids composing the colony, and brings them into relation with one another. It is probably in virtue of this system that the *avicularia* are enabled to continue their movements, and retain their irritability after the death of the polypides.

The muscular system is well developed, and consists of various muscular bands, with special functions attaching to each. The most important fasciculi are the retractor muscles, which retract the upper portion of the polypide within the cell. These muscles arise from the inner surface of the endocyst near the bottom of the cell, and are inserted into the upper part of the œsophagus. The polypide, when retracted, is again exserted, chiefly by the action of the 'parietal muscles,' which are in the form of circular bundles running transversely round the cell.

As far as is known, all the *Polyzoa* are hermaphrodite, each polypide containing an ovary and testis (*fig.* 72, 2). The ovary is situated near the summit of the cell, and is attached to the inner surface of the endocyst. The testis is situated at the bottom of the cell, and a curious cylindrical appendage, called the 'funiculus,' usually passes from it to the fundus of the stomach. The products of generation, i.e. the spermatozoa and ova, are discharged into the perigastric space, where fecundation takes place; but it is not certainly known how the impregnated ova escape into the external medium.

As already mentioned, continuous gemmation occurs in all the *Polyzoa*, the fresh zoöids thus produced remaining attached to the organism from which they were budded forth, and thus giving rise to a compound growth.

A form of discontinuous gemmation, however, occurs in many of the *Polyzoa*, in which certain singular bodies, called 'statoblasts,' are developed in the interior of the polypide. The statoblasts are found, in certain seasons, lying loose in the perigastric cavity. In form 'they may be generally described as lenticular bodies, varying, according to the species, from an orbicular to an elongated-oval figure, and enclosed in a horny shell, which consists of two concavo-convex discs united by their margins, where they are further strengthened by a ring which runs round the entire margin, and is of different structure from the discs. . . . . When the statoblasts are placed under circumstances favouring their development, they open by the separation from one another of the two faces, and there then escapes from them a young *Polyzoön*, already in an advanced stage of development, and in all essential respects resembling the adult individual in whose cell the statoblasts were produced.'—(Allman.) The statoblasts are formed as buds upon the 'funiculus'—the cord already alluded to as extending from the testis to the stomach—upon which they may usually be seen in different stages of growth. They do not appear to be set free from the perigastric space prior to the death of the adult, and when liberated, they are enabled to float near the surface of the water, in consequence of the cells of the marginal ring, or 'annulus,' being spongy and filled with air. They must be looked upon as '*gemmæ* peculiarly encysted, and destined to remain for a period in a quiescent or pupa-like state.'—(Allman.)

As regards the development of the *Polyzoa*, the embryo upon its emergence from the ovum presents itself as a ciliated, free-swimming, sac-like body, from which the polypide is subsequently produced by a process of gemmation.

Divisions of the Polyzoa.—The *Polyzoa* are divided into two divisions or orders—the *Phylactolæmata*, distinguished by the possession of a bilateral horse-shoe-shaped lophophore, and of an 'epistome' arching over the mouth; and the *Gymnolæmata*, in which the lophophore is orbicular, and there is no epistome.

TABLE OF THE DIVISIONS OF THE POLYZOA.—(AFTER BUSK.)

Order I. Phylactolæmata.
Lophophore bilateral; mouth with an epistome.
Sub-order 1. *Lophopea* (fresh-water).
Arms of lophophore free or obsolete; consistence horny, sub-calcareous.
Sub-order 2. *Pedicellinea* (marine).
Arms of lophophore united at their extremities; consistence soft, fleshy.
Order II. Gymnolæmata.
Lophophore orbicular, or nearly so; no epistome.
Sub-order 3. *Paludicellea* (fresh-water).
Polypide completely retractile; evagination of tentacular sheath imperfect; consistence horny or sub-calcareous.
Sub-order 4. *Cheilostomata* (marine).
Polypide completely retractile; evagination perfect; orifice of cell sub-terminal, of less diameter than the cell, and usually closed with a movable lip or shutter, sometimes by a contractile sphincter; cells not tubular; consistence calcareous, horny, or fleshy.
Sub-order 5. *Cyclostomata* (marine).
Cell tubular; orifice terminal, of the same diameter as the cell, without any movable apparatus for its closure; consistence calcareous.
Sub-order 6. *Ctenostomata* (marine).
Orifice of the cell terminal, furnished with a usually setose fringe for its closure; cells distinct, arising from a common tube; consistence horny or carnose.

CHAPTER XLIII.

TUNICATA.

CLASS II. TUNICATA (*Ascidioida*).—The members of this class of the *Molluscoida* are defined as follows:—'Alimentary canal suspended in a double-walled sac, but not capable of protrusion and retraction; mouth opening into the bottom of a respiratory sac, whose walls are more or less completely lined by a network of bloodvessels.'—(Allman.) Animal simple or composite. An imperfect heart in the form of a simple tube open at both ends.

The Tunicaries are all marine, and are protected by a leathery, elastic integument, which takes the place of a shell. In appearance a solitary Ascidian (*fig.* 74) may be compared to a double-necked jar with two prominent apertures situated

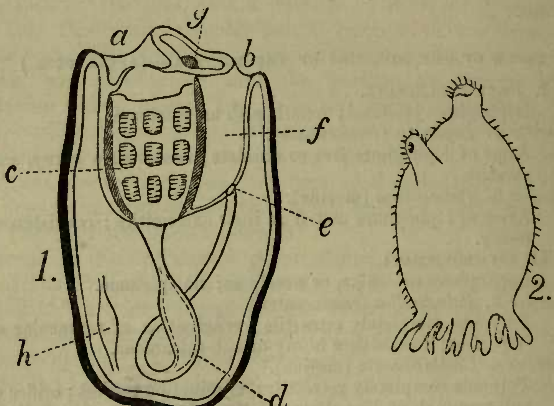


Fig. 74.—Morphology of Tunicata. 1. Diagram of a Tunicary (after Allman); *a*. Oral aperture; *b*. Atrial aperture; *c*. Pharyngeal or branchial sac, with its rows of ciliated apertures; *d*. Alimentary canal, with its hæmal flexure; *e*. Anus; *f*. Atrium; *g*. Nervous ganglion. 2. *Cynthia papillosa*, a simple Ascidian. (After Woodward.)

close to one another at the free extremity of the animal, one of these being the mouth, whilst the other serves as an excretory aperture. The covering of an Ascidian is composed of two layers. Of these the outer is called the 'external tunic,' or 'test,' and is distinguished by its coriaceous or cartilaginous consistence. It is also remarkable for containing a substance which gives the same chemical reactions as cellulose, and is probably identical with this characteristic vegetable product. The test is lined by a second coat, which is termed the 'second tunic' or 'mantle,' and which is mainly composed of longitudinal and circular muscular fibres. By means of these the animal is endowed with great contractility, and has the power of ejecting water from its branchial aperture with considerable force. The mantle lines the test, but is only slightly and loosely attached to it, especially near the apertures. The mouth is usually surrounded by a circlet of small, non-ciliated, non-retractile tentacles, and opens into a large chamber (*fig.* 74, 1, *c*), which usually occupies the greater part of the cavity of the mantle, and has its walls perforated by numerous apertures. This is known variously as the 'pharynx,' the 'respiratory sac,' or the 'branchial sac.' (It must be remembered that the aperture here spoken of as the mouth can only be looked upon in this light, provided that the respiratory sac is looked upon as the pharynx. By Professor Allman, whose definition is given at the head of this chapter, this view is not accepted, and consequently the internal or *inferior* opening of the respiratory sac is regarded as the true mouth.) Inferiorly the respiratory sac leads by a second aperture into an œsophagus, which opens into a capacious stomach. From the stomach an intestine is continued, generally with few flexures, to the anal aperture, which does not communicate directly with the exterior, but opens into the bottom of a second chamber, which is called the 'cloaca' (*fig.* 74, 1, *f*). Superiorly the cloaca communicates with the external medium, by means of the second aperture in the test. The first bend of the intestine is such that, if continued, it would bring the anus on the opposite side of the mouth to that on which the nervous ganglion is situated. The intestine, therefore, is said to have a 'hæmal flexure;' whereas the flexure in the case of the *Polyzoa* is 'neural.' The intestine, however, in the *Tunicata* does not preserve this primary hæmal flexure, but is again bent to the neural side of the body, the nervous ganglion coming finally to be situated between the mouth and the rectum. As just stated, the anus is not in direct communication with the exterior, but opens into a large cavity, called the 'cloaca,' or 'atrial chamber,' which, in turn, opens externally by the second aperture of the animal. This cloaca is a large sac lined by a membrane which 'is reflected like a serous sac on the viscera, and constitutes the "third tunic" or "peritoneum."' From the cloaca, 'it is reflected over both sides of the pharynx' (respiratory sac) 'extending towards its dorsal part, very nearly as far as that structure which has been termed the "endostyle." It then passes from the sides of the pharynx to the body-walls, on which the right and left lamellæ become continuous, so as to form the lining of the chamber into which the second aperture leads, or the "atrial chamber." Posteriorly, or at the opposite end of the atrial chamber to its aperture, its lining membrane (the "atrial tunic") is reflected to a greater or less extent over the intestine and circulatory organs. . . . . Where the atrial tunic is reflected over the sides of the pharynx, the two enter into a more or less complete union, and the surfaces of contact become perforated by larger or smaller, more or less numerous apertures. Thus, the cavity of the pharynx acquires a free communication with that of the atrium; and as the margins of the pharyngo-atrial apertures are fringed with cilia, working towards the interior of the body, a current is produced, which sets in at the oral aperture and out by the atrial opening, and may be readily observed in a living Ascidian.'—(Huxley.)

As regards some points in the above description, Professor Allman does not agree with Huxley, but believes, on the other hand, 'that the walls of the atrium simply surround the branchial sac, without being reflected on its sides, and that the branchial sac is, therefore, properly *within* the cavity of the atrium.'

In structure, the pharyngeal, or 'branchial' sac is composed of a series of longitudinal and transverse bars, which cross each other at right angles, and thus give rise to a series of quadrangular meshes, the margins of which are fringed with vibratile cilia. These bars are hollow, and are really vessels, which open on each side into two main, longitudinal sinuses, the so-called 'branchial,' or 'thoracic' sinuses—one of which is placed along the hæmal side of the pharynx, whilst the other runs along its neural aspect. The function of the entire perforated pharynx is clearly respiratory.

The *Tunicata* possess a distinct heart, consisting of a simple muscular tube, which is open at both ends, and is not provided with valves. In consequence of this, the circulation, in the majority of Tunicaries, is periodically reversed, the blood being propelled in one direction for a certain number of contractions, and being then driven for a like period in an opposite direction; 'so that the two ends of the heart are alternately arterial and venous.'

The nervous system consists of a single ganglion placed on one side of the oral aperture, between it and the anus, in all known *Tunicata*, except in the aberrant form *Appendicularia*.

The only organs of sense are pigment-spots, or ocelli, placed between the oral tentacles, and an auditory capsule, sometimes containing an otolith. These organs, however, do not appear to be constantly present.

With the exception of *Doliolum* and *Appendicularia*, all the *Tunicata* are hermaphrodite. The reproductive organs are situated in the fold of the intestine, and their efferent duct opens into the atrium. The embryo Tunicate is at first free, and is shaped like the tadpole of a frog, swimming by means of a long caudal appendage.

Amongst the Salpians a species of alternation of generations has been observed. A solitary Salpian produces long chains of embryos, which remain organically connected throughout their entire life. Each individual of these associated specimens produces solitary young which are often very unlike their parents, and these again give rise to the aggregated forms.

The *Tunicata* are often spoken of as exhibiting three main types of structure, which give origin to as many sections, known respectively as the *solitary*, the *social*, and the *compound* forms. In the 'solitary' Tunicaries the individuals, however produced, remain entirely distinct, or if not so primitively, they become so. In the 'social' Ascidians the organism consists of a number of zoöids, produced by gemmation and permanently connected together by a vascular canal, or 'stolon,' composed of a prolongation of the common tunic, through which the blood circulates. Finally, in the 'compound' forms, the zoöids become aggregated into a common mass, their tests being fused together, but there being no internal union.

Homologies of the Tunicata. — The general resemblance between a solitary Ascidian and a single polypide of a *Polyzoön* is extremely obvious; each consisting of a double-walled sac, containing a freely suspended alimentary canal, with a distinct mouth and anus, and a nervous ganglion placed between the two. The chief feature in the *Tunicata*, as to the exact nature of which there is much difference of opinion, is the branchial or respiratory sac. By Professor Allman, this is believed to be truly homologous with the tentacular crown of the *Polyzoa*, and the oral tentacles of the Tunicaries are believed to be something superadded, and not represented at all in the *Polyzoa*. By Professor Huxley, on the other hand, the branchial sac is looked upon as an enormously developed pharynx, and the oral tentacles are regarded as a rudimentary representative of the tentacular crown of the *Polyzoa*.

Divisions of the Tunicata.—By Professor Huxley the following arrangement of the Tunicaries is adopted:—

Class Tunicata.

Order I. *Ascidia branchialia.*

Branchial sac occupying the whole, or nearly the whole, length of the body; intestine lying on one side of it. (*Ascidiadæ*, *Botryllus*, *&c.*)

Order II. *Ascidia abdominalia.*

Alimentary canal completely behind the branchial sac, which is comparatively small. (*Salpa*, *Doliolum*, *&c.*)

Order III. *Ascidia larvalia.*

Permanent larval form. (*Appendicularia.*)

The following subdivisions are those adopted by Mr. Woodward.

CLASS TUNICATA.

Fam. I. *Ascidiadæ* (Simple Ascidians).

Animal simple, fixed, solitary or gregarious; oviparous; sexes united; branchial sac simple, or disposed in (8—18) deep and regular folds.

Fam. II. *Clavellinidæ* (Social Ascidians).

Animal compound, fixed; individuals connected by creeping tubular prolongations of the common tunic through which the blood circulates, (or by a common gelatinous base). Reproduction effected by ova, or by gemmation from the common tube; the new individuals remaining attached to the parent, or becoming completely free.

Fam. III. *Botryllidæ* (Compound Ascidians).

Animals compound, fixed, their tests fused, forming a common mass in which they are imbedded in one or more groups. Individuals not connected by any internal union; oviparous and gemmiparous.

Fam. IV. *Pyrosomidæ.*

Animal compound, free and oceanic.

Fam. V. *Salpidæ.*

Animals free and oceanic; alternately solitary and aggregated.

CHAPTER XLIV.

BRACHIOPODA.

CLASS III. BRACHIOPODA (*Palliobranchiata*).—The members of this class are defined by the possession of a body protected by a bivalve shell, which is lined by an expansion of the integument, or 'mantle.' The mouth is furnished with two long cirriferous arms. The nervous system consists of a single ganglion, placed in the re-entering angle between the gullet and the rectum, so that the intestine has a 'neural flexure.'

The *Brachiopoda* are essentially very similar in structure to the *Polyzoa*, from which they are distinguished by the fact that they are never composite, and by the possession of a bivalve, calcareous, or sub-calcareous shell. They are commonly known as 'Lamp-shells,' and are all inhabitants of the sea, being sometimes free, but being more commonly attached to some solid object. From the presence of a bivalve shell, the Brachiopods have often been placed near the true bivalve

Mollusca (the *Lamellibranchiata*), but their organisation is very much inferior, and there are also sufficient differences in the shell to justify their separation.

The two valves of the shell of any *Brachiopod* are articulated together by an apparatus of teeth and sockets, or are kept in apposition by muscular action alone. One of the valves is always slightly, sometimes greatly, larger than the other, so that the shell is said to be 'inequivalve.' As regards the contained animal, the position of the valves is anterior and posterior, so that they are, therefore, termed respectively the 'ventral' and 'dorsal' valves. In the ordinary bivalve *Mollusca* (*Lamellibranchiata*), on the other hand, the two valves of the shell are usually of the same size (equivalve), and they are situated upon the sides of the animal, so that, instead of being dorsal and ventral, they are now termed 'right' and 'left' valves. The ventral valve in the shell of the *Brachiopoda* is usually the largest, and usually possesses a prominent curved beak. The beak is sometimes perforated by a 'foramen,' or terminal aperture, through which there is transmitted a muscular peduncle, whereby the shell is attached to some foreign object. In some cases, however (as in *Lingula*), the peduncle simply passes between the apices of the valves, and there is no foramen; whilst in others (as in *Crania*), the shell is merely attached by the substance of the ventral valve. The dorsal, or smaller, valve is always free, and is never perforated by a foramen.

In intimate structure, the shell of most of the *Brachiopoda* consists 'of flattened prisms, of considerable length, arranged parallel to one another with great regularity, and at a very acute angle—usually only about 10° or 12°—with the surfaces of the shell.'—(Carpenter.) In most cases, also, the shell is perforated by a series of minute canals, which pass from one surface of the shell to the other, in a more or less vertical direction, usually widening as they approach the external surface. These canals give the shell a 'punctated' structure, and in the living animal they contain cæcal tubuli, or prolongations, from the mantle, which are considered by Huxley as analogous to the vascular processes by which in many Ascidians the muscular tunic, or 'mantle,' is attached to the outer tunic, or 'test.' In some of the *Brachiopoda* (as in the *Rhynchonellidæ*) the shell is 'impunctate,' or is devoid of this singular canal system.

The inner surface of the valves of the shell is lined by expansions of the integument which secrete the shell, and are called the 'lobes' of the 'pallium,' or 'mantle.' The digestive organs and muscles occupy a small space near the beak of the shell, which is partitioned off by a membranous septum, which is perforated by the aperture of the mouth. The remainder of the cavity of the shell is almost filled by two long oral processes, which are termed the 'arms,' and from which the name of the class has been derived. These organs are lateral prolongations of the margins of the mouth, usually of great length, closely coiled up, and fringed on one side with lateral processes, or 'cirri.' In many Brachiopods the arms are supported upon a more or less complicated internal calcareous framework, or skeleton, which is sometimes called the 'carriage-spring apparatus.'

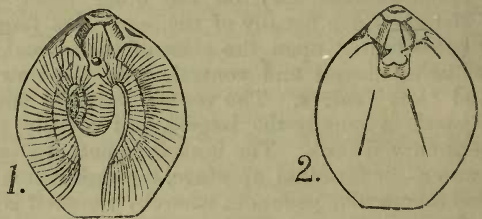


Fig. 75.—Brachiopoda. *Terebratula vitrea.* 1. Showing the ciliated 'arms.' 2. Showing the shell with its loop. (After Woodward.)

The mouth conducts by an œsophagus into a distinct stomach, surrounded by a well developed, granular liver. The intestine has a 'neural flexure,' and 'either ends blindly in the middle line, or else terminates in a distinct anus between the pallial lobes.'—(Huxley.)

Within the pallial lobes there is a remarkable system of more or less branched tubes, anastomosing with one another, and ending in cæcal extremities. This, which has been termed by Huxley the 'atrial system,' communicates with the perivisceral cavity by means of two or four organs which are called 'pseudo-hearts,' and which were at one time supposed to be true hearts. 'Each pseudo-heart is divided into a narrow, elongated, external portion (the so-called "ventricle") which communicates, as Dr. Hancock has proved, by a small apical aperture with the pallial cavity; and a broad, funnel-shaped, inner division (the so-called "auricle") communicating, on the one hand, by a constricted neck, with the so-called "ventricle;" and, on the other, by a wide, patent mouth with a chamber which occupies most of the cavity of the body proper, and sends more or less branched diverticula into the pallial lobes.'—(Huxley.) This system of the atrial canals has been looked upon as a rudimentary respiratory apparatus; but its function is more probably to act as an excretory organ, and also to convey away the reproductive elements, the organs for which are developed in various parts of its walls. By Woodward, the pseudo-hearts are regarded as oviducts, and it is stated that they have been found to contain mature ova, so that there can be little doubt but that this view of their nature is the correct one.

The function of respiration is probably performed, mainly, if not entirely, by the cirriferous oral arms, as it appears chiefly to be by the homologous tentacular crown of the *Polyzoa*. A true vascular system and a distinct heart are present in some, at any rate, of the *Brachiopoda*, but this subject is still involved in considerable obscurity. In *Terebratula* the heart is in the form of a unilocular, pyriform vesicle, placed on the dorsal surface of the stomach.

The nervous system consists of a principal ganglion, of no great size, placed in the re-entering angle between the gullet and the rectum.

The sexes are most probably united in the same individual. Little is known of the development of any of the *Brachiopoda*, but the embryo is doubtless free-swimming and locomotive.

CLASSIFICATION OF THE BRACHIOPODA.—(AFTER DAVIDSON.)

CLASS BRACHIOPODA.

Fam. I. *Terebratulidæ.*

Shell minutely punctate; ventral valve with a prominent beak perforated by a foramen for the emission of a muscular peduncle, whereby the animal is fixed to some solid object. Foramen partially surrounded by a deltidium of one or two pieces. Oral appendages entirely or partially supported by calcified processes, usually in the form of a loop, and always fixed to the dorsal valve.

Genera.—Terebratula (with *Terebratulina*, and *Waldheimia*), *Terebratella*, *Stringocephalus*, &c.

Fam. II. *Thecididæ.*

Shell fixed to the sea-bottom by the beak of the larger or ventral valve; structure punctated. Oral processes united in the form of a bridge over the visceral cavity; cirrated arms folded upon themselves, and supported by a calcareous loop.

Genus.—Thecidium.

Fam. III. *Spiriferidæ.*

Animal free, or rarely attached by a muscular peduncle. Shell punctated or unpunctated. Arms largely developed, and entirely supported by a thin, shelly, spirally-rolled lamella.

Genera.—Spirifer, Spiriferina, Cyrtia, Athyris, &c.

Fam. IV. *Koninckidæ.*

Animal unknown. Shell free; valves unarticulated (?). Oral arms supported by two lamellæ, spirally-coiled.

Genus.—Koninckia.

Fam. V. *Rhynchonellidæ.*

Animal free, or attached by a muscular peduncle issuing from an aperture situated under the extremity of the beak of the ventral valve.

Arms spirally rolled, flexible, and supported only at their origin by a pair of short curved shelly processes. Shell-structure fibrous and impunctate.

Genera.—Rhynchonella, Pentamerus, Porambonites, &c.

Fam. VI. *Strophomenidæ.*

Animal unknown; some probably free, others attached, during the whole or a portion of their existence, by a muscular peduncle. No calcified supports for the arms. Shell with a straight hinge-line, and a low triangular area in each valve. Shell-structure fibrous and punctated.

Genera.—Orthis, Orthisina, Strophomena and *Leptæna.*

Fam. VII. *Productidæ.*

Animal unknown. Shell entirely free, or attached to marine bottoms by the substance of the beak; valves either regularly articulated, or kept in place by muscular action. No calcified support for the oral appendages.

Genera.—Producta, Chonetes, Strophalosia, Aulosteges.

Fam. VIII. *Calceolidæ.**

Animal unknown. Shell probably free; valves not articulated; ventral valve pyramidal with a large, flat, triangular area; dorsal valve flat, semicircular, with a straight hinge-line. No foramen, or muscular, or vascular impressions.

Genus.—Calceola.

Fam. IX. *Craniadæ.*

Animal fixed to submarine objects by the substance of the shell of the ventral valve. Arms fleshy and spirally coiled; no hinge, or articulating processes; upper or dorsal valve patelliform (i.e. limpet-shaped).

Genus.—Crania.

Fam. X. *Discinidæ.*

Animal attached by means of a muscular peduncle, passing through the ventral or lower valve, by means of a slit in its hinder portion or a circular foramen excavated in its substance. Arms fleshy, valves unarticulated.

Genera.—Discina, Trematis, Siphonotreta, Acrotreta.

Fam. XI. *Lingulidæ.*

Animal fixed by a muscular peduncle passing out between the beaks of the valves; arms fleshy, unsupported by calcified processes. Shell unarticulated, sub-equivalve, texture horny.

Genera.—Lingula, Obolus.

CHAPTER XLV.

DISTRIBUTION OF MOLLUSCOIDA.

DISTRIBUTION OF MOLLUSCOIDA IN SPACE.—The *Polyzoa*, like all the *Molluscoida*, are exclusively aquatic in their habits, but, unlike the remaining two classes, they are not exclusively

* Recent researches have thrown some doubt upon the position of *Calceola* amongst the *Brachiopoda*, and have tended to show that it is a very abnormal type of Rugose Coral, provided with a lid or operculum.

confined to the sea. The marine *Polyzoa* are of almost universal occurrence in all seas. The fresh-water *Polyzoa*, however, not only differ materially from their marine brethren in structure, but appear to have a much more limited range, being, as far as is yet known, confined to the North Temperate Zone. Britain can claim the great majority of the described species of fresh-water *Polyzoa*, but this is probably due to the more careful scrutiny to which this country has been subjected.

The *Tunicata* are cosmopolitan in their distribution, and are found in all seas, the Mediterranean appearing to be especially rich in members of this class. Four genera are pelagic in their habits, and several are found in the Arctic Regions.

The *Brachiopoda*, though of very partial occurrence, have a wide range in space, being found both in tropical seas, and in the Arctic Ocean. Their bathymetrical range is also very wide, extending from the littoral zone, almost to the greatest depths at which animal life has hitherto been detected.

Distribution of Molluscoida in Time.—The *Polyzoa* have left abundant traces of their past existence in the stratified series, commencing in the Lower Silurian Rocks and extending up to the present day. The *Oldhamia* of the Cambrian Rocks of Ireland, and the *Graptolites* have been supposed to belong to the *Polyzoa*, but the former is very possibly a plant, and the latter should be referred to the *Hydrozoa*. Of undoubted *Polyzoa*, the marine orders of the *Cheilostomata* and *Cyclostomata* are alone known with certainty to be represented. Several Palæozoic genera, such as *Fenestella* (the Lace-coral), *Ptilodictya*, *Ptilopora*, &c. are exclusively confined to this epoch, and do not extend into the Secondary Rocks. Amongst the Mesozoic formations, the Chalk is especially rich in *Polyzoa*, over two hundred species having been already described from this horizon alone. In the Tertiary period, the Coralline Crag (Pleiocene) is equally conspicuous for the great number of the members of this class.

The *Tunicata*, from the nature of their bodies, are not known to occur in a fossil condition.

The *Brachiopoda* are found from the Cambrian Rocks up to the present day, and present us with an example of a group which appears to be slowly dying out. Nearly two thousand extinct species have been described, and the class appears to have attained its maximum in the Silurian epoch, which is, for this reason, sometimes called the 'Age of Brachiopods.' Numerous genera and species are found also in both the Devonian and Carboniferous Formations. In the Secondary Rocks *Brachiopoda* are still abundant, though less so than in the Palæozoic period. In the Tertiary epoch a still further diminution takes place, and at the present day we are not acquainted with a hundred living forms. Of the families of *Brachiopoda*, the *Productidæ*, *Strophomenidæ* and *Spiriferidæ* are the more important extinct types. Of the genera, the most persistent is the genus *Lingula*, which commences in the Cambrian Rocks, and has maintained its place up to the present day, though it appears to be gradually dying out.

According to Woodward :—'the hingeless genera attained their maximum in the Palæozoic age, and only three now survive (*Lingula*, *Discina*, *Crania*)—the representatives of as many distinct families. Of the genera with articulated valves, those provided with spiral arms appeared first, and attained their maximum while the *Terebratulidæ* were still few in number. The subdivision with calcareous spires disappeared with the Liassic period, whereas the genus *Rhynchonella* still exists. Lastly, the typical group, *Terebratulidæ*, attained its maximum in the Chalk period and is scarcely yet on the decline.'

MOLLUSCA PROPER.

CHAPTER XLVI.

LAMELLIBRANCHIATA.

Division II. Mollusca Proper.—This division includes those members of the sub-kingdom *Mollusca*, in which *the nervous system consists of three principal pairs of ganglia; and there is always a well developed heart, which is never composed of fewer than two chambers.*

The *Mollusca* proper may be roughly divided into two great sections, respectively termed the *Acephala* and the *Encephala* (or *Cephalophora*), characterised by the absence or presence of a distinctly differentiated head. The headless, or Acephalous, Molluscs correspond to the class *Lamellibranchiata*; also distinguished, at first sight, by the possession of a bivalve shell. The Encephalous Molluscs are more highly organised, and are divided into three classes, viz. the *Gasteropoda*, the *Pteropoda*, and the *Cephalopoda*. The shell in these three classes is of very various nature, but they all possess a singular and complicated series of lingual teeth; hence they are grouped together by Professor Huxley under the name of *Odontophora*.

Class I. Lamellibranchiata, or Conchifera.—The members of this class are characterised by the absence of a distinctly differentiated head, and by having the body more or less completely protected in a bivalve shell. There are two lamellar gills on each side of the body, the intestine has a neural flexure, and there is no odontophore.

The *Lamellibranchiata* are commonly known as the bivalve shell-fish, such as Mussels, Cockles, Oysters, Scallops, &c., and they are all either marine or inhabitants of fresh water.

Though they agree with the *Brachiopoda* in possessing a shell which is composed of two pieces or valves, there are, nevertheless, many points in which the shell of a Lamellibranch is distinguishable from that of a Brachiopod, irrespective of the great difference in the structure of the animal in each. The shell in the *Brachiopoda*, as we have seen, is rarely, or never, quite equivalve, and always has its two sides equally developed (equilateral); whilst the valves are placed antero-posteriorly as regards the animal, one in front and one behind, so that they are 'dorsal' and 'ventral.' In the *Lamellibranchiata*, on the other hand, the two valves are usually of nearly equal size (equivalve), and are more developed on one side than on the other (inequilateral); whilst their position as regards the animal is always *lateral*, so that they are properly termed 'right' and 'left' valves, instead of 'ventral' and 'dorsal.'

The following are the chief points to be noticed in connection with the shell of any Lamellibranch. Each valve of the shell may be regarded as essentially a hollow cone, the apex of which is turned more or less to one side; so that more of the shell is situated on one side of the apex than on the other. The apex of the valve is called the 'umbo,' or 'beak,' and is always turned towards the mouth of the animal. Consequently, the side of the shell towards which the umbones are turned is the 'anterior' side, and it is usually the shortest half of the shell. The longer half of the shell, from which the umbones turn away, is called the 'posterior' side, but in some cases this is equal to, or even shorter than, the anterior side. The side of the shell where the beaks are situated, and where the valves are united to one another, is called the 'dorsal' side, and the opposite margin, along which the shell opens, is called the 'ventral' side, or 'base.' The *length* of the shell is measured from its anterior to its posterior margin, and its *breadth* from the dorsal margin to the base.

At the dorsal margin the valves are united to one another for a shorter or longer distance, along a line, which is called the 'hinge-line.' The union is effected in most shells by means of a series of parts which interlock with one another (the 'teeth'), but these are sometimes absent, when the shell is said to be 'edentulous.' Posterior to the umbones, in most bivalves, is another structure passing between the valves, which is called the 'ligament,' and which is usually composed of two parts, either distinct or combined with one another. These two parts are known as the 'external ligament' (or the ligament proper) and the 'cartilage,' and they constitute the agency whereby the shell is opened, but one or other of them may be absent. The ligament proper is outside the shell, and consists of a band of horny fibres, passing from one valve to the other just *behind* the beaks, in such a manner that it is put upon the stretch when the shell is closed. The cartilage, or internal ligament, is lodged between the hinge-lines of the two valves, generally in one or more 'pits,' or in special processes of the shell. It consists of elastic fibres placed perpendicularly between the surfaces by which it is contained, so that they are necessarily shortened and compressed when the valves are shut. To open the shell, therefore, it is simply necessary for the animal to relax the muscles which are provided for the closure of the valves, whereupon the elastic force of the ligament and cartilage is sufficient of itself to open the shell.

The body in the *Lamellibranchiata* is always enclosed in an expansion of the dorsal integument, which constitutes the 'mantle' or 'pallium,' whereby the shell is secreted. The lobes of the mantle are right and left, and not anterior and posterior as are the mantle-lobes of the *Brachiopoda*. Towards its circumference the mantle is more or less completely united to the shell, leaving in its interior, when the soft parts are removed, a more or less distinctly impressed line, which is called the 'pallial line,' or 'impression.'

There is no distinctly differentiated head in any of the *Lamellibranchiata*, and the mouth is simply placed at the anterior extremity of the body. It is furnished with membranous processes or 'palpi' (usually four in number), but there is no dental apparatus. The mouth opens into a gullet, which conducts to a distinct stomach. The intestine has its first flexure neural, perforates the wall of the heart, and terminates posteriorly in a distinct anus, which is always placed near the respiratory aperture. The liver is large and well developed.

There is always a distinct heart, composed either of an auricle and ventricle, or of two auricles and a ventricle. The ventricle propels the blood into the arteries, by which it is distributed through the body. From the arteries it passes into the veins, and is conducted to the gills, where it is aërated, and is finally returned to the auricles.

The respiratory organs in all the *Lamellibranchiata* consist of two lamelliform gills, placed on each side of the body. The gills are in the form of membranous plates, composed usually of tubular rods, which support a network of capillary vessels, and are covered with vibrating cilia, whereby a circulation of the water is maintained over their surfaces. In some bivalves the margins of the mantle are united to one another, so that a closed branchial chamber is produced, and in the others the arrangements for the admission of fresh, and the expulsion of effete, water are equally perfect, though there is no such chamber. In those in which the mantle-lobes are united at their margins, there are two orifices, one of which serves to admit fresh water, whilst the effete water is expelled by the other. The margins of these 'inhalent' and 'exhalent' apertures are often drawn out and extended into long muscular tubes or 'siphons,' which may be either free, or may be united to one another along one side, and which can usually be, partially or entirely, retracted within the shell by means of special muscles, called the 'retractor-muscles of the siphons.' These siphons are more especially characteristic of those Lamellibranchs which spend their existence buried in the sand, protruding their respiratory tubes in order to obtain water, and with it such nutrient particles as the water may contain. The presence or absence of retractile siphons can be readily determined merely by inspection of the dead shell. In those bivalves in which siphons are not present, or if present are not retractile, the 'pallial line' in the interior of the shell is unbroken in its curvature, and presents no indentation (*Integro-pallialia*). In those, on the other hand, in which retractile siphons exist, the pallial line does not run in an unbroken curve, but is deflected inwards posteriorly, so as to form an indentation, or bay, which is termed the 'pallial sinus,' or 'siphonal impression,' and is caused by the insertion of the retractor-muscle of the siphon. Those bivalves in which this sinus exists form the section *Sinu-pallialia* (*fig.* 76).

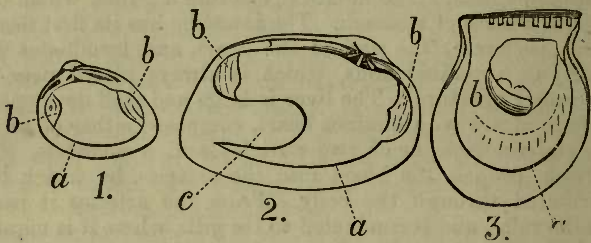


Fig. 76.—Shells of Lamellibranchiata. 1. *Cyclas amnica*, a dimyary shell with an entire pallial line. 2. *Tapes pullastra*, a dimyary shell with an indented pallial line. 3. *Perna ephippium*, a monomyary shell. (After Woodward.) *a*. Pallial line; *b*. Muscular impressions left by the adductors; *c*. Siphonal impression.

The nervous system of the *Lamellibranchiata* is composed of the three normal ganglia—the cephalic, the pedal, and the parieto-splanchnic, or branchial.

The majority of the bivalves are diœcious, but in some the sexes are united in the same individual. The young are hatched before they leave the parent, and are, when first liberated, ciliated and free-swimming.

The muscular system of the Lamellibranchs is well developed. Besides the muscular margin of the mantle, and the muscles of the siphons (when these exist), there are also present other muscles, of which the most important are the muscles which close the shell, and those which form the 'foot.' The 'foot' is present in the majority of bivalves, though it is not such a striking feature as in the *Gasteropoda*. It is essentially a muscular organ, developed upon the ventral surface of the body, its retractor-muscles usually leaving distinct impressions, or scars (the 'pedal impressions') in the interior of the shell. In many, the foot subserves locomotion, but in the attached bivalves it is rudimentary. In some—such as the ordinary Mussel—the foot is subsidiary to a special gland, which secretes the tuft of silky threads ('byssus'), whereby the shell is attached to foreign objects. This gland secretes a viscous material, which the foot moulds into threads.

The valves of the shell are brought together by one or two muscles, which are called the 'adductor muscles'—those bivalves with only one being called *Monomyaria*, whilst those which possess two are termed *Dimyaria*. In most there are two adductor muscles passing between the inner surfaces of the valves, one being placed anteriorly in front of the mouth, the other posteriorly on the neural side of the intestine. In the monomyary bivalves the posterior adductor is the one which remains, and the anterior adductor is absent. The adductors leave distinct 'muscular impressions' in the interior of the shell, so that it is easy to determine whether there has been one only, in any given specimen, or whether two were present.

The habits of the *Lamellibranchiata* are very various. Some, such as the Oyster (*Ostrea*), and the Scallop (*Pecten*), habitually lie on one side, the lower valve being the deepest, and the foot being wanting, or rudimentary. Others, such as the Mussel (*Mytilus*), and the *Pinna*, are attached to some foreign object by an apparatus of threads, which is called the 'byssus,' and is secreted by a special gland. Others are fixed to some solid body by the substance of one of the valves. Many, such as the *Myas*, spend their existence sunk in the sand of the sea-shore, or in the mud of estuaries. Others, as the *Pholades* and *Lithodomi*, bore holes in rock or wood, in which they live. Finally, many are permanently free and locomotive.

The *Lamellibranchiata* are divided into two sections, according as respiratory siphons are absent or present, as follows:—

SECTION A. ASIPHONIDA.—Animal without respiratory siphons; mantle-lobes free; the pallial line simple and not indented (*Integro-pallialia*).

This section comprises the families *Ostreidæ*, *Aviculidæ*, *Mytilidæ*, *Arcadæ*, *Trigoniadæ*, and *Unionidæ*.

SECTION B. SIPHONIDA.—Animal with respiratory siphons; mantle-lobes more or less united.

Two subdivisions are comprised in this section. In the first *the siphons are short, and the pallial line is simple* (*Integro-pallialia*); as is seen in the families *Chamidæ*, *Hippuritidæ*, *Tridacnidæ*, *Cardiadæ*, *Lucinidæ*, *Cycladidæ*, and *Cyprinidæ*.

The second subdivision (*Sinu-pallialia*) is distinguished by the possession of *long respiratory siphons*, and *a sinuated pallial line*, and it comprises the families *Veneridæ*, *Mactridæ*, *Tellinidæ*, *Solenidæ*, *Myacidæ*, *Anatinidæ*, *Gastrochænidæ*, and *Pholadidæ*.

SYNOPSIS OF THE FAMILIES OF THE LAMELLIBRANCHIATA.

SECTION A. ASIPHONIDA.

Fam. 1. *Ostreidæ.* — Shell inequivalve, slightly inequilateral, free or attached; hinge usually edentulous. Ligament internal. Lobes of the mantle entirely separated; the foot small and byssiferous, or wanting. A single adductor. Ill. Gen. *Ostrea*, *Pecten*, *Spondylus*, *&c.*

Fam. 2. *Aviculidæ.*—Shell inequivalve, very oblique, attached by a byssus; hinge nearly, or quite, edentulous. Mantle-lobes free; anterior adductor small, leaving its impression within the umbo; posterior adductor large and sub-central. Foot small. Ill. Gen. *Avicula*, *Inoceramus*, *Pinna.*

Fam. 3. *Mytilidæ.*—Shell equivalve, umbones *anterior*, hinge edentulous; anterior muscular impression small, posterior large. Shell attached by a byssus. Mantle-lobes united between the siphonal apertures. Foot cylindrical, grooved, and byssiferous. Ill. Gen. *Mytilus*, *Modiola*, *Dreissena.*

Fam. 4. *Arcadæ.*—Shell equivalve; hinge long, with many comb-like equal teeth. Muscular impressions nearly equal. Mantle-lobes separated; foot large, bent, and deeply grooved. Ill. Gen. *Arca*, *Pectunculus*, *Cucullæa.*

Fam. 5. *Trigoniadæ.*—Shell equivalve, trigonal; hinge-teeth few, diverging; umbones directed posteriorly. Mantle open; foot long and bent. Ill. Gen. *Trigonia*, *Axinus.*

Fam. 6. *Unionidæ.*—Shell usually equivalve, with a large external ligament. Anterior hinge-teeth thick and striated; posterior laminar, or wanting. Mantle-lobes united between the siphonal apertures. Foot very large, compressed, byssiferous in the fry. Ill. Gen. *Unio*, *Anodon*, *Mülleria.*

SECTION B. SIPHONIDA.

Subdivision I. *Integro-pallialia.*—Siphons short, pallial line simple.

Fam. 7. *Chamidæ.* — Shell inequivalve, attached; hinge-teeth 2–1 (two in one valve and one in the other). Adductor impressions large. Mantle closed; pedal and siphonal orifices small and nearly equal. Foot very small. Ill. Gen. *Chama*, *Diceras.*

Fam. 8. *Hippuritidæ.* — 'Shell inequivalve, unsymmetrical, thick, attached by the *right* umbo; umbones frequently camerated; structure and sculpturing of valves dissimilar; ligament internal; hinge-teeth 1–2; adductor impressions 2, large, those of the left valve on prominent apophyses; pallial line simple, sub-marginal.' —(Woodward.) Ill. Gen. *Hippurites*, *Radiolites*, *Caprinella.*

Fam. 9. *Tridacnidæ.*—Shell equivalve; ligament external; muscular impressions blended, sub-central. Animal attached by a byssus, free. Mantle-lobes extensively united; pedal aperture large; siphonal orifices surrounded by a thickened pallial border. Foot finger-like and byssiferous. Ill. Gen. *Tridacna.*

Fam. 10. *Cardiadæ.*—Shell equivalve, heart-shaped, with radiating ribs; cardinal teeth 2; lateral teeth 1–1, in each valve. Mantle open in front, siphons usually very short; foot large, sickle-shaped. Ill. Gen. *Cardium, Hemicardium, Conocardium.*

Fam. 11. *Lucinidæ.*—Shell orbicular, and free; hinge-teeth 1 or 2; lateral teeth 1–1, or obsolete. Mantle-lobes open below, with one or two siphonal orifices behind; foot elongated, cylindrical, or strap-shaped. Ill. Gen. *Lucina, Diplodonta, Kellia.*

Fam. 12. *Cycladidæ.*—Shell sub-orbicular, closed; hinge with cardinal and lateral teeth; ligament external. Mantle open in front; 1–2 siphons, more or less united. Foot large, tongue-shaped. Ill. Gen. *Cyclas, Cyrena.*

Fam. 13. *Cyprinidæ.*—Shell equivalve, closed; ligament external; cardinal teeth 1–3 in each valve, and usually a posterior tooth. Mantle-lobes united behind by a curtain pierced with two siphonal orifices. Foot thick, and tongue-shaped. Ill. Gen. *Cyprina, Astarte, Isocardia.*

Subdivision II. *Sinu-pallialia.*—Respiratory siphons large; pallial line sinuated.

Fam. 14. *Veneridæ.*—Shell regular, sub-orbicular or oblong; ligament external; hinge with usually 3 diverging teeth in each valve. Animal usually free and locomotive; mantle with a rather large anterior opening; siphons unequal, more or less united. Foot tongue-shaped, compressed, sometimes grooved and byssiferous. Ill. Gen. *Venus, Cytherea, Venerupis.*

Fam. 15. *Mactridæ.*—Shell equivalve, trigonal; hinge with two diverging cardinal teeth, and usually with anterior and posterior lateral teeth. Mantle more or less open in front; siphons united, with fringed orifices; foot compressed. Ill. Gen. *Mactra, Lutraria.*

Fam. 16. *Tellinidæ.*—Shell free, usually equivalve and closed; cardinal teeth 2 at most, laterals 1–1, sometimes wanting. Ligament on the shortest side of the shell, sometimes internal. Mantle widely open in front. Siphons separate, long and slender; foot tongue-shaped, compressed. Ill. Gen. *Tellina, Psammobia, Donax.*

Fam. 17. *Solenidæ.*—Shell elongated, gaping at both ends; ligament external; hinge-teeth usually 2–3. Siphons short and united (in the long-shelled genera), or longer and partly separate (in the genera with shorter shells). Foot very large and powerful. Gills prolonged into the branchial siphon. Ill. Gen. *Solen, Cultellus, Solecurtus.*

Fam. 18. *Myacidæ.*—Shell gaping posteriorly. Mantle almost entirely closed; siphons united, partly or wholly retractile. Foot very small. Ill. Gen. *Mya, Panopæa, Glycimeris.*

Fam. 19. *Anatinidæ.*—Shell often inequivalve, with an external ligament. Mantle-lobes more or less united; siphons long, more or less united. Foot small. Ill. Gen. *Anatina, Pholadomya, Myochama.*

Fam. 20. *Gastrochænidæ.*—Shell equivalve, gaping, with thin edentulous valves, sometimes cemented to a calcareous tube. Mantle-margins thick in front, united, with a small pedal aperture. Siphons very long, united. Foot finger-shaped. Ill. Gen. *Gastrochæna, Saxicava, Aspergillum.*

Fam. 21. *Pholadidæ.*—Shell gaping at both ends, without hinge or ligament, often with accessory valves. Animal club-shaped or worm-like, with a short, truncated foot. Mantle closed in front. Siphons long, united to near their extremities. Ill. Gen. *Pholas, Xylophaga, Teredo.*

CHAPTER XLVII.

GASTEROPODA.

Division Encephala or Cephalophora.—The remaining three classes of the Mollusca proper all possess a distinctly differentiated head, and are all provided with a peculiar masticatory apparatus, which is known as the 'odontophore.' For the first of these reasons they are often grouped together under the name *Encephala*; and for the second reason they are united by Huxley into a single great division, under the name of *Odontophora.* Whichever name be adopted, the three classes in question (viz. the *Gasteropoda*, *Pteropoda* and *Cephalopoda*) certainly show many points of affinity, and form a very natural division of the *Mollusca.* The *Pteropoda*, as being the lowest class, should properly be treated of first, but it will conduce to a clearer understanding of their characters, if the *Gasteropoda* are considered first.

Class II. Gasteropoda.—The members of this class are characterised by being never included in a bivalve shell; locomotion being effected by means of a broad, horizontally flattened ventral disc—the 'foot'—or by a vertically flattened, ventral, fin-like organ. Flexure of intestine hæmal or neural.

This class includes all those Molluscous animals which are commonly known as 'univalves,' such as the land-snails, sea-snails, whelks, limpets, &c. The shell, however, is sometimes composed of several pieces (multivalve), and in many there is either no shell at all, or nothing that would be generally recognised as such. In none is there a bivalve shell.

In their habits the Gasteropods show many differences, some being sedentary, but the great majority being free and locomotive. In these latter, locomotion may be effected by the successive contractions and expansions of a muscular foot; but some possess the power of swimming freely by means of a modified fin-like foot.

In most of the *Gasteropoda* the body is unsymmetrical, and is coiled up spirally, 'the respiratory organs of the left side being usually atrophied.'—(Woodward.) The body is enclosed in a 'mantle,' which is not divided into two lobes as in the *Lamellibranchiata*, but is continuous round the body. Locomotion is effected by means of the 'foot,' which is usually a broad muscular disc, developed upon the ventral surface of the body, and not exhibiting any distinct division into parts. In the *Heteropoda*, however, the foot exhibits a division into three portions—an anterior, the 'propodium;' a middle, the 'mesopodium;' and a posterior lobe, or 'metapodium.'

In others, again, the upper and lateral surfaces of the foot are expanded into muscular side-lobes, which are called 'epipodia.' In many cases the metapodium, or posterior portion of the foot, secretes a calcareous, horny, or fibrous plate, which is called the 'operculum,' and which serves to close the orifice of the shell when the animal is retracted within it.

The head in most of the *Gasteropoda* is very distinctly marked out, and is provided with two tentacles and with two eyes, which are often placed upon long stalks. The mouth is sometimes furnished with horny jaws, and is always provided with a singular masticatory apparatus, called the 'tongue,' or 'odontophore.' 'It consists essentially of a cartilaginous cushion, supporting, as on a pulley, an elastic strap, which bears a long series of transversely disposed teeth. The ends of the strap are connected with muscles attached to the upper and lower surface of the hinder extremities of the cartilaginous cushions; and these muscles, by their alternate contractions, cause the toothed strap to work backwards and forwards over the end of the pulley formed by its anterior end. The strap consequently acts, after the fashion of a chain-saw, upon any substance to which it is applied, and the resulting wear and tear of its anterior teeth are made good by the incessant development of new teeth in the secreting sac in which the hinder end of the strap is lodged.'—(Huxley.) The teeth of the odontophore ('lingual teeth') are composed of silica, and are usually arranged in a central ('rachidian'), and two lateral ('pleural') rows. The mouth leads by a gullet into a distinct stomach, which is sometimes provided with calcareous plates for the trituration of the food. The intestine is long, and its first flexure is commonly 'hæmal,' or towards that side of the body on which the heart is situated; though in some the flexure is 'neural.' Distinct salivary glands are usually present, and the liver is well developed.

Fig. 77.—Part of the lingual ribbon or odontophore of *Valvata piscinalis*, magnified.

A distinct heart is usually present, composed of an auricle and ventricle. Respiration is very variously effected; one great division (*Branchiogasteropoda*) being constructed to breathe air by means of water; whilst in another section (*Pulmogasteropoda*) the respiration is aërial. In the former division respiration may be effected in three ways. Firstly, there may be no specialised respiratory organ, the blood being simply exposed to the water in the thin walls of the mantle-cavity (as in some of the *Heteropoda*). Secondly, the respiratory organs may be in the form of outward processes of the integument, exposed in tufts on the back and sides of the animal (as in the *Nudibranchiata*). Thirdly, the respiratory organs are in the form of pectinated or plume-like branchiæ, contained in a more or less complete branchial chamber formed by an inflection of the mantle. In many members of this last section, the water obtains access to the gills by means of a tubular prolongation or folding of the mantle, forming a 'siphon,' the effete water being expelled by another posterior siphon similarly constructed. In the air-breathing Gasteropods, the breathing-organ is in the form of a pulmonary chamber, formed by an inflection of the mantle, and having a distinct aperture for the admission of air.

The nervous system in the *Gasteropoda* has its normal composition of three principal pairs of ganglia, the supra-œsophageal or cerebral, the infra-œsophageal or pedal, and the parieto-splanchnic; but there is a tendency to the aggregation of these in the neighbourhood of the head. The organs of sense are the two eyes, and auditory capsules placed at the bases of the tentacles, the latter being tactile organs.

The sexes are mostly distinct, but in some they are united in the same individual. The young, when first hatched, are *always* provided with an embryonic shell, which in the adult may become concealed in a fold of the mantle, or may be entirely lost. In the branchiate Gasteropods the embryo is protected by a small nautiloid shell, within which it can entirely retract itself; and it is enabled to swim freely by means of two ciliated lobes arising from the sides of the head; thus, in many respects, resembling the permanent adult condition of the *Pteropoda*.

Shell of the Gasteropoda.—The shell of the Gasteropods is composed either of a single piece (univalve), or of a number of plates succeeding one another from before backwards (multivalve). The univalve shell is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which may retain this shape (as in *Dentalium*), but is usually coiled up into a spiral. The 'spiral univalve' may, in fact, be looked upon as the typical form of the shell in the *Gasteropoda*. In some cases the coils of the shell—termed technically the 'whorls'—are hardly in contact with one another (as in *Vermetus*.) More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases, the whorls of the shell are coiled round a central axis *in the same plane*, when the shell is said to be 'discoidal' (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming 'turreted,' 'trochoid,' 'turbinated,' &c. This last form is the one which may be looked upon as most characteristic of the Gasteropods, the shell being composed of a number of whorls, passing obliquely round a central axis, or 'columella,' having the embryonic shell, or 'nucleus,' at its apex, and having the mouth, or 'aperture,' of the shell placed at the extremity of the last and largest of the whorls, termed the 'body-whorl.' The lines or grooves formed by the junction of the whorls are termed the 'sutures,' and the whorls above the body-whorl constitute the 'spire' of the shell. The axis of the shell (columella) round which the whorls are coiled is usually solid, when the shell is said to be 'imperforate;' but it is sometimes hollow, when the shell is said to be 'perforated,' and the aperture of the axis near the mouth of the shell is called the 'umbilicus.' The margin of the 'aperture' of the shell is termed the 'peristome,' and is composed of an outer and inner lip, of which the former is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called 'varices.' In most of the phytophagous Gasteropods (*Holostomata*) the aperture of the shell (*fig.* 79) is unbrokenly round, or 'entire,' but in the carnivorous forms (*Siphonostomata*) it is notched, or produced into a canal. Often there are two of these canals, an anterior, and a posterior, but they do not necessarily indicate the nature of the food, as their function is to protect the respiratory

Fig. 78.—*Helix aspersa*, the Spotted Snail, a 'spiral' Gasteropod.

siphons. The animal withdraws into its shell by a retractor-muscle, which passes into the foot, or is attached to the operculum; its scar or impression being placed, in the spiral univalves, upon the columella.

In the multivalve Gasteropods, the shell is composed of eight transverse imbricated plates, which succeed one another from before backwards.

CHAPTER XLVIII.

DIVISIONS OF THE GASTEROPODA.

The *Gasteropoda* are divided into two primary sections, or sub-classes, according as the respiratory organs are adapted for breathing air, directly, or dissolved in water: termed respectively the *Pulmonifera*, or *Pulmogasteropoda*, and the *Branchifera*, or *Branchiogasteropoda*.

Sub-class A. Branchifera, or Branchiogasteropoda.—In this sub-class *respiration is aquatic*, effected by the thin walls of the mantle-cavity, by external branchial tufts, or by pectinated, or plume-like gills, contained in a more or less complete branchial chamber. *Flexure of intestine hæmal.*

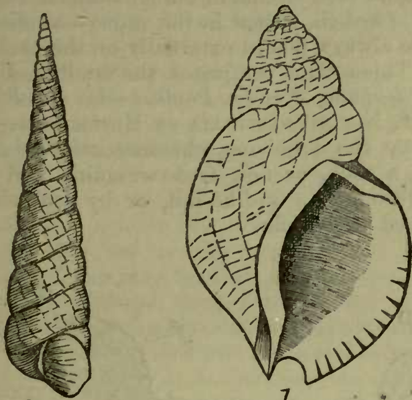
This sub-class comprises three orders, viz. the *Prosobranchiata*, the *Opisthobranchiata*, and the *Nucleobranchiata* or *Heteropoda*.

Order I. Prosobranchiata.—The members of this order are defined as follows:—'*Abdomen* well developed, and protected by a shell, into which the whole animal can usually retire. *Mantle* forming a vaulted chamber over the back of the head, in which are placed the excretory orifices, and in which the branchiæ are almost always lodged. *Branchiæ* pectinated or plume-like, situated (*proson*) in advance of the heart. *Sexes* distinct.'—(M.-Edwards. See Woodward's *Manual.*)

The order *Prosobranchiata* includes all the most characteristic members of the Branchiate Gasteropods, and is divisible into two sections, termed respectively *Siphonostomata* and *Holostomata*, according as the aperture of the shell is notched or produced into a canal, or is simply rounded and 'entire.'

The *Siphonostomata*, of which the Common Whelk (*Buccinum undatum*) may be taken as an example, are all marine, and are mostly carnivorous in their habits. The following families are comprised in this section:—*Strombidæ* (Wing-shells), *Muricidæ*, *Buccinidæ* (Whelks), *Conidæ* (Cones), *Volutidæ*, and *Cypræidæ* (Cowries).

The *Holostomata*, of which the Common Periwinkle (*Littorina littorea*) is a good example, are either spiral, or limpet-



a b

Fig. 79.—Gasteropoda. *a.* Holostomatous shell (*Turritella communis*). *b.* Siphonostomatous shell (*Buccinum undatum*).

shaped, in some few instances tubular, or multivalve; the aperture of the shell being in most cases entire. They are mostly plant-eaters, and they may be either marine or inhabitants of fresh water. The following families are included in this section:—*Naticidæ*, *Pyramidellidæ*, *Cerithiadæ*, *Melaniadæ*, *Turritellidæ*, *Littorinidæ* (Periwinkles), *Paludinidæ* (River-snails), *Neritidæ*, *Turbinidæ* (Top-shells), *Haliotidæ* (Ear-shells), *Fissurellidæ* (Key-hole Limpets), *Calyptræidæ* (Bonnet Limpets), *Patellidæ* (Limpets), *Dentalidæ* (Tooth-shells), and *Chitonidæ*.

ORDER II. OPISTHOBRANCHIATA. This order is defined as follows:—

'*Shell* rudimentary, or wanting. *Branchiæ* arborescent or fasciculated, not contained in a special cavity, but more or less completely exposed on the back and sides, towards the rear (*opisthen*) of the body. Sexes united.'—(M.-Edwards. See Woodward's *Manual.*)

The *Opisthobranchiata*, or 'Sea-slugs,' may be divided into two sections, the *Tectibranchiata* and *Nudibranchiata*, according as the branchiæ are protected or are uncovered.

The first section, that of the *Tectibranchiata*, is distinguished by the fact that the animal is usually provided with a shell, both in the larval and adult state, and that the branchiæ are protected by the shell, or by the mantle. Under this family are included the families of the *Tornatellidæ*, *Bul-*

lidæ (Bubble-shells), *Aplysiadæ* (Sea-hares), *Pleurobranchidæ* and *Phyllidiadæ*.

In the second section, that of the *Nudibranchiata*, the animal is destitute of a shell, except in the embryo condition, and the branchiæ are always placed externally on the back or sides of the body. This section comprises the families, *Doridæ* (Sea-lemons), *Tritoniadæ*, *Æolidæ*, *Phyllirhoidæ*, and *Elysiadæ*.

ORDER III. NUCLEOBRANCHIATA OR HETEROPODA.—This order is defined by the following characteristics :—Animal provided with a shell, or not, free-swimming and pelagic; locomotion effected by a fin-like tail, or by a fan-shaped, vertically-flattened ventral fin.

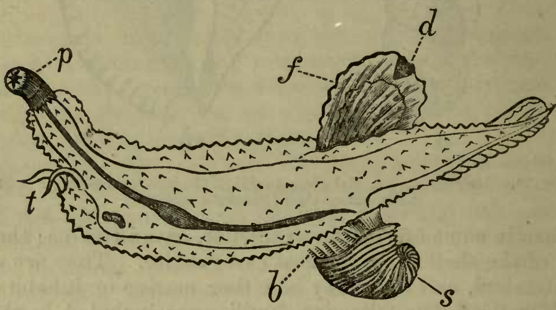


Fig. 80.—Heteropoda. *Carinaria cymbium*. *p*. Proboscis; *t*. Tentacles; *b*. Branchiæ; *s*. Shell; *f*. Foot; *d*. Disc. (After Woodward.)

The *Heteropoda* are pelagic in their habits, and are found swimming at the surface of the sea. They are to be regarded as the most highly organised of all the *Gasteropoda*, at the same time that they are not the most typical members of the class. Some of them can retire completely within their shells, closing them with an operculum, but most have large bodies, and the shell is either small or entirely wanting. They swim by means of a flattened ventral fin, or by an elongated tail, and adhere at pleasure to sea-weed by a small sucker situated on the side of the fin. These organs are merely modifications of the foot of the ordinary Gasteropods; the fin-like tail being the 'metapodium' (as shown by its occasionally carrying an operculum), the sucker being the 'mesopodium,' and the ventral fin being a modified 'propodium.' Respiration is sometimes carried on by distinct branchiæ, but in many cases these are wanting, and the function is performed simply by the walls of the pallial chamber.

The *Heteropoda* are divided into the two families *Firolidæ* and *Atlantidæ*, the former characterised by having a small shell covering the circulatory and respiratory organs, or by having no shell at all; whilst in the latter, there is a well developed shell, into which the animal can retire, and an operculum is often present.

SUB-CLASS B. PULMONIFERA OR PULMOGASTEROPODA.—In this sub-class of the *Gasteropoda respiration is aërial*, and is carried on by an inflection of the mantle, forming a pulmonary chamber, into which air is admitted by an external aperture. The *flexure of the intestine is neural*, and the sexes are united in the same individual.

The *Pulmonifera* include the ordinary land-snails, slugs, pond-snails, &c., and are usually provided with a well developed shell, though this may be rudimentary (as in the slugs), or even wanting. Though formed to breathe air directly, many of the members of this sub-class are capable of inhabiting fresh water. They are divided into two sections as follows :—

Section I. *Inoperculata.—Animal not provided with an operculum to close the shell.* In this section are included the families *Helicidæ* (Land-snails), *Limacidæ* (Slugs), *Oncidiadæ*, *Limnæidæ* (Pond-snails), and *Auriculidæ*.

Section II. *Operculata.—Shell closed by an operculum.* In this section are included the families *Cyclostomidæ*, and *Aciculidæ*.

SYNOPSIS OF THE FAMILIES OF THE GASTEROPODA.—(AFTER WOODWARD.)

SECTION A. BRANCHIFERA. Respiration aquatic, by the walls of the mantle-cavity, or by branchiæ.

ORDER I. PROSOBRANCHIATA. The branchiæ situated (*proson*) in advance of the heart.

Division a. Siphonostomata. Margin of the shell-aperture notched or produced into a canal.

Fam. 1. *Strombidæ.* Shell with an expanded lip, deeply notched near the canal. Operculum claw-shaped. Foot narrow, adapted for leaping. Ill. Gen. *Strombus, Pteroceras.*

Fam. 2. *Muricidæ.* Shell with a straight anterior canal, the aperture entire posteriorly. Foot broad. Ill. Gen. *Murex, Triton, Pyrula, Fusus.*

Fam. 3. *Buccinidæ.* Shell notched anteriorly, or with the canal abruptly reflected, producing a kind of varix on the front of the shell. Ill. Gen. *Buccinum, Nassa, Purpura, Cassis, Harpa, Oliva.*

Fam. 4. *Conidæ.* Shell inversely conical, with a long, narrow aperture, the outer lip notched at or near the suture. Operculum minute, lamellar. Ill. Gen. *Conus, Pleurotoma.*

Fam. 5. *Volutidæ.* Shell turreted or convolute, the aperture notched in front; the columella obliquely plaited. No operculum. Foot very large; mantle often reflected over the shell. Ill. Gen. *Voluta, Mitra, Marginella.*

Fam. 6. *Cypræidæ.* Shell convolute, enamelled; spire concealed, aperture narrow, channelled at each end. Outer lip thin in the young shell, but thickened and inflected in the adult. Foot broad; mantle forming lobes which meet over the back of the shell. Ill. Gen. *Cypræa*, *Ovulum*.

Division b. Holostomata. Margin of the shell-aperture 'entire,' rarely notched or produced into a canal.

Fam. 1. *Naticidæ*. Shell globular, of few whorls, with a small spire, outer lip acute, pillar often callous. Foot very large; mantle-lobes hiding more or less of the shell. Gen. *Natica*, *Sigaretus*.

Fam. 2. *Pyramidellidæ*. Shell turreted, with a small aperture, sometimes with one or more prominent plaits on the columella. Operculum horny, imbricated. Ill. Gen. *Pyramidella*, *Chemnitzia*, *Eulima*.

Fam. 3. *Cerithiadæ*. Shell spiral, turreted; aperture channelled in front, with a less distinct posterior canal. Lip generally expanded in the adult. Operculum horny and spiral. Ill. Gen. *Cerithium*, *Potamides*, *Aporrhais*.

Fam. 4. *Melaniadæ*. Shell spiral, turreted; aperture often channelled or notched in front; outer lip acute. Operculum horny and spiral. Ill. Gen. *Melania*, *Paludomus*.

Fam. 5. *Turritellidæ*. Shell tubular, or spiral, often turreted; upper part partitioned off; aperture simple. Operculum horny, many-whorled. Foot very short. Branchial plume single. Ill. Gen. *Turritella*, *Vermetus*, *Scalaria*.

Fam. 6. *Littorinidæ*. Shell spiral, top-shaped, or depressed; aperture rounded and entire; operculum horny and pauci-spiral. Ill. Gen. *Littorina*, *Solarium*, *Rissoa*, *Phorus*.

Fam. 7. *Paludinidæ*. Shell conical or globular; aperture rounded and entire; operculum horny or shelly. Ill. Gen. *Paludina*, *Ampullaria*, *Valvata*.

Fam. 8. *Neritidæ*. Shell thick, globular, with a very small spire; aperture semi-lunate, its columellar side expanded; outer lip acute. Operculum shelly, sub-spiral. Ill. Gen. *Nerita*, *Pileolus*, *Neritina*.

Fam. 9. *Turbinidæ*. Shell turbinated (top-shaped), or pyramidal, nacreous inside. Operculum horny and multi-spiral, or calcareous and pauci-spiral. Ill. Gen. *Turbo*, *Trochus*, *Delphinula*, *Euomphalus*.

Fam. 10. *Haliotidæ*. Shell spiral, ear-shaped, or trochoid, aperture large, nacreous. Outer lip notched or perforated. No operculum. Mantle-margin with a posterior fold or siphon, occupying the slit or perforation in the shell. Metapodium rudimentary. Ill. Gen. *Haliotis*, *Scissurella*, *Pleurotomaria*, *Murchisonia*, *Ianthina*.

Fam. 11. *Fissurellidæ*. Shell conical, patelliform, with a notch in the anterior margin, or a perforation at its apex, which is occupied by an anal siphon. Muscular impression horse-shoe-shaped, open in front. Ill. Gen. *Fissurella*, *Emarginula*, *Parmophorus*.

Fam. 12. *Calyptræidæ*. Shell patelliform, with a more or less spiral apex; interior simple, or divided by a shelly process to which the adductor muscles are attached. Ill. Gen. *Calyptræa*, *Pileopsis*.

Fam. 13. *Patellidæ*. Shell conical, with the apex turned forwards; muscular impression horse-shoe-shaped, open in front. Foot as large as the margin of the mantle. Respiratory organ in the form of one or two branchial plumes, lodged in a cervical cavity; or of a series of lamellæ surrounding the animal between the body and the mantle. Ill. Gen. *Patella*, *Acmæa*.

Fam. 14. *Dentalidæ*. Shell tubular, symmetrical, curved, open at both ends. Aperture circular. Foot pointed, with symmetrical side-lobes. Gen. *Dentalium.**

Fam. 15. *Chitonidæ.* Shell multivalve, composed of eight, transverse, imbricated plates. Animal with broad creeping foot; branchiæ forming a series of lamellæ between the foot and the mantle, round the posterior part of the body. Ill. Gen. *Chiton*, *Cryptochiton.*

ORDER II. OPISTHOBRANCHIATA. Branchiæ placed towards the rear (*opisthen*) of the body.

Section a. Tectibranchiata. Branchiæ covered by the shell or mantle; a shell in most. Sexes united.

Fam. 1. *Tornatellidæ.* Shell external, spiral, or convoluted; aperture long and narrow; columella plaited. Ill. Gen. *Tornatella*, *Cinulia.*

Fam. 2. *Bullidæ.* Shell convoluted, thin; spire small or concealed, lip sharp. Animal more or less investing the shell. Ill. Gen. *Bulla*, *Cylichna*, *Philine.*

Fam. 3. *Aplysiadæ.* Shell absent, or rudimentary and concealed by the mantle. Animal slug-like, with extensive side-lobes (epipodia) reflected over the back and shell. Ill. Gen. *Aplysia*, *Dolabella.*

Fam. 4. *Pleurobranchidæ.* Shell patelliform, or concealed, rarely wanting. Mantle or shell covering the back of the animal. Ill. Gen. *Pleurobranchus*, *Umbrella*, *Tylodina.*

Fam. 5. *Phyllidiadæ.* Animal shell-less, covered by a mantle. Ill. Gen. *Phyllidia*, *Diphyllidia.*

Section b. Nudibranchiata. Animal destitute of a shell in the adult condition. Branchiæ external, on the back or sides of the body.

Fam. 6. *Doridæ.* Ill. Gen. *Doris.*

Fam. 7. *Tritoniadæ.* Ill. Gen. *Tritonia*, *Scyllæa.*

Fam. 8. *Æolidæ.* Ill. Gen. *Æolis*, *Glaucus.*

Fam. 9. *Phyllirhoidæ.* Gen. *Phyllirhoe.*

Fam. 10. *Elysiadæ.* Ill. Gen. *Elysia*, *Acteonia.*

ORDER III. NUCLEOBRANCHIATA OR HETEROPODA. Shell present or absent. Animal free-swimming and pelagic, with a fin-like tail, or a flattened ventral fin.

Fam. 1. *Firolidæ.* Body large; branchiæ exposed on the back, or covered by a small hyaline shell; locomotion by means of a ventral fin, and a tail-fin. Ill. Gen. *Carinaria*, *Firola.*

Fam. 2. *Atlantidæ.* Animal furnished with a well developed shell into which it can retire. Branchiæ contained in a dorsal mantle-cavity. Shell symmetrical, discoidal, sometimes with an operculum. Ill. Gen. *Atlanta*, *Bellerophon*, *Maclurea.*

SECTION B. PULMONIFERA. Respiration aërial, by means of a pulmonary chamber.

DIVISION I. INOPERCULATA. *Shell not provided with an operculum.*

Fam. 1. *Helicidæ.* Shell external, capable of containing the whole animal. Ill. Gen. *Helix*, *Bulimus*, *Clausilia*, *Pupa.*

Fam. 2. *Limacidæ.* Shell rudimentary, usually internal or partly concealed by the mantle. Ill. Gen. *Limax*, *Parmacella*, *Testacella.*

Fam. 3. *Oncidiadæ.* Shell wanting. Animal slug-like. Gen. *Oncidium*, *Vaginulus.*

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* *Dentalium* is placed by Professor Huxley amongst the *Pteropoda*, from its rudimentary head, the neural flexure of the intestine, the nature of the epipodia, and the characters of the larva.

Fam. 4. *Limnæidæ.* Shell thin, horn-coloured, well developed. Aperture simple, lip sharp. Ill. Gen. *Limnæa*, *Physa*, *Ancylus*, *Planorbis*.

Fam. 5. *Auriculidæ.* Shell spiral, with a horny epidermis; aperture elongated, denticulated. Ill. Gen. *Auricula*, *Conovulus*.

DIVISION II. OPERCULATA. *Shell with an operculum.*

Fam. 6. *Cyclostomidæ.* Shell spiral, rarely elongated, often depressed. Aperture nearly circular. Operculum spiral. Ill. Gen. *Cyclostoma*, *Cyclophorus*, *Pupina*.

Fam. 7. *Aciculidæ.* Shell elongated, cylindrical; operculum thin, and sub-spiral. Gen. *Acicula*, *Geomelania*.

CHAPTER XLIX.

PTEROPODA.

CLASS III. PTEROPODA. The *Pteropoda* are defined by being *free and pelagic*, swimming by means of two wing-like appendages (epipodia), developed from each side of the anterior extremity of the body. The flexure of the intestine is neural.

As to the position of the *Pteropoda* in the Molluscan scale, they must be looked upon as inferior in organisation to any of the *Gasteropoda*, of which class they are often regarded as the lowest division. They permanently represent, in fact, the transient, larval, stage of the sea-snails.

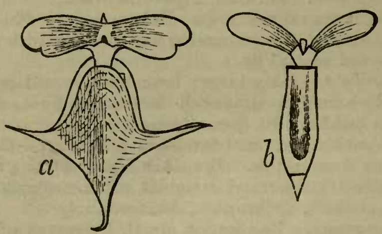

Fig. 81.—Pteropoda. *a. Cleodora pyramidata.* *b. Cuvieria columnella.* (After Woodward.)

The Pteropods are all of small size, and are found swimming at the surface of the open ocean, often in enormous numbers. Locomotion is effected by two wing-like fins, developed from the sides of the head, and composed of the greatly developed 'epipodia.' The true 'foot' is rudimentary and rarely distinct, but the 'metapodium' is sometimes provided with an operculum. There is usually a symmetrical glassy shell (*fig.* 81), either consisting of a dorsal and ventral plate united, or forming a spiral, but in some cases the body is naked. The head is rudimentary, and bears the mouth, which is occasionally tentaculate, and which is furnished with an odontophore. There is a muscular stomach, and a well developed liver, and the flexure of the intestine is neural, so that the anus is situated on the ventral surface of the body.

The heart consists of an auricle and ventricle. The respiratory organ is very rudimentary, and consists of a ciliated surface, which is either entirely unprotected, or may be contained in a branchial chamber.

The ganglia of the nervous system 'are concentrated into a mass *below* the œsophagus' (Woodward), and the eyes are rudimentary.

The sexes are united in all the Pteropods.

The *Pteropoda* are divided into two orders, termed *Thecosomata* and *Gymnosomata*; the former characterised by possessing an external shell, and an indistinct head; the latter by being devoid of a shell, and by having a distinct head, with fins attached to the neck.

SYNOPSIS OF THE FAMILIES OF THE PTEROPODA.—(AFTER WOODWARD.)

ORDER I. THECOSOMATA.

Animal with an external shell; head indistinct; foot and tentacles rudimentary; mouth situated in a cavity formed by the union of the locomotive organs. Respiratory organs contained within a mantle-cavity.

Fam. 1. *Hyaleidæ.*

Shell symmetrical, straight or curved, globular, or needle-shaped. Ill. Gen. *Hyalea*, *Cleodora*, *Theca*, *Conularia.*

Fam. 2. *Limacinidæ.*

Shell minute, spiral, sometimes operculate. Ill. Gen. *Limacina*, *Spirialis.*

ORDER II. GYMNOSOMATA.

Animal naked, without mantle or shell, head distinct; fins attached to the sides of the neck; gill indistinct.

Fam. 3. *Cliidæ.*

Body fusiform, foot distinct, with a central and posterior lobe; head with tentacles. Ill. Gen. *Clio*, *Pneumodermon.*

CHAPTER L.

CEPHALOPODA.

CLASS IV. CEPHALOPODA.—The members of this class are defined by the possession of eight or more arms placed in a circle round the mouth; the body is enclosed in a muscular mantle-sac, and there are two or four plume-like gills within the mantle. There is an anterior tubular orifice (the 'infundibulum' or 'funnel'), through which the effete water of respiration is expelled. The flexure of the intestine is neural.

The *Cephalopoda*, comprising the Cuttle-fishes, Squids, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine, and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by means of the arms which surround the mouth, and which are usually provided with numerous suckers or 'acetabula.' They are, also, enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular 'funnel,' the reaction of which causes the animal to move in the opposite direction.

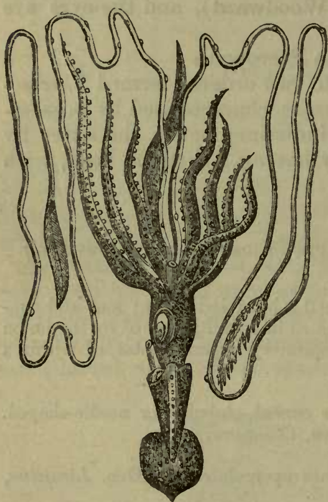

Fig. 82.—Cephalopoda. *Loligopsis*, a 'decapod' Cuttle-fish.

The majority of the living Cephalopods are naked, possessing only an internal skeleton, and this often a rudimentary one; but the Argonant (Paper Nautilus), and the Pearly Nautilus, are protected with an external shell, through the nature of this is extremely different in the two forms.

The integument in the Cuttle-fishes is provided with numerous little sacs, containing pigment-granules of different colours, and termed 'chromatophores.' By means of these many species can change their colours rapidly, under irritation or excitement.

The body in the *Cephalopoda* is symmetrical, and is enclosed in an integument which may be regarded as a modification of the mantle of the other *Mollusca*. Ordinarily there is a tolerably distinct separation of the body into an anterior cephalic portion (*prosoma*), and a posterior portion, enveloped in the mantle, and containing the viscera (*metasoma*). The head is very distinct, bearing a pair of large globular eyes, and having the mouth in its centre. The mouth is surrounded by a circle of eight, ten, or more, long muscular processes, or 'arms,' which are generally provided with rows of suckers.

Each sucker, or 'acetabulum,' consists of a cup-shaped cavity, the muscular fibres of which converge to the centre, where there is a little muscular eminence or papilla. When the sucker is applied to any surface, the contraction of the radiating muscular fibres depresses the papilla so as to produce a vacuum below it, and in this way each sucker acts most efficiently as an adhesive organ. In some forms (*Decapoda*) the base of the papilla, or piston, is surrounded by a horny dentated ring, and in some others (as in *Onychoteuthis*) the papillæ are produced into long claws. In the Octopod Cuttle-fishes there are only eight arms, and these are all nearly alike. In the Decapod Cuttle-fishes there are ten arms, but two of these—called 'tentacles,'—are much longer than the others and bear suckers only at their extremities, which are enlarged and club-shaped. In the Pearly Nautilus, the arms are numerous, and are devoid of suckers.

The arms are really produced by an extension of the margins of the 'foot,' or of the part corresponding to the foot of the other *Mollusca*. The 'antero-lateral parts of each side of the foot extend forwards beyond the head, uniting with it and with one another; so that, at length, the mouth, from having been situated, as usual, above the anterior margin of the foot, comes to be placed in the midst of it. The two epipodia, on the other hand, unite posteriorly above the foot, and where they coalesce, give rise either to a folded muscular expansion, the edges of which are simply in apposition, as in the *Nautilus*; or to an elongated flexible tube, the apex of which projects beyond the margin of the mantle, called the "funnel," or "infundibulum," as in the dibranchiate *Cephalopoda*.'—(Huxley.)

The mouth leads into a buccal cavity, containing two powerful, horny or partially calcareous, mandibles, working vertically like the beak of a bird; together with an 'odontophore' or 'tongue,' the anterior part of which is sentient, whilst the remainder is covered with recurved spines. The buccal cavity conducts by an œsophagus—into which salivary glands pour their secretion—to a stomach, from which an intestine is continued, with a neural flexure, to open on the ventral surface of the animal at the base of the funnel. In many cases there is also a special gland, called the 'ink-bag,' for the secretion of an inky fluid, which the animal discharges into the water, so as to enable it to escape when menaced or pursued. The duct of the ink-bag opens at the base of the funnel; but this apparatus is entirely wanting in the Tetrabranchiate Cephalopods, where in consequence of the presence of an external shell, this means of defence is not needed.

The respiratory organs are in the form of two or four plume-like gills, placed on the sides of the body in a branchial cavity which opens anteriorly on the under surface of the body. At the base of each gill, in the Cuttle-fishes, is a special contractile cavity, whereby the venous blood, returned from the body, is driven through the branchiæ. In addition to these accessory organs—the so-called 'branchial hearts'—there is a true systemic heart, by which the aërated blood received from the gills is propelled through the body. The admission of water to the branchiæ is effected by the expansion of the mantle so as to allow the entrance of the outer water into the pallial chamber. The mantle then contracts, and the water is forcibly expelled through the funnel, which is provided with a valve permitting the egress of water but preventing its ingress. By a repetition of this process, not only is respiration effected, but locomotion is simultaneously subserved; the jets of water expelled from the funnel, by their reaction, driving the animal in the opposite direction.

The nervous system is formed upon essentially the same plan as in the other *Mollusca*, but it is more concentrated, and the supra-œsophageal or cerebral ganglia are protected by a cartilage, which is to be regarded as a rudimentary cranium. This structure, therefore, presents us with the nearest approach which we have yet met with, to the Vertebrate type of organisation.

The sexes in all the *Cephalopoda* are in different individuals, and the reproductive process in the Dibranchiate section of the class (Cuttle-fishes) is attended with some very singular phenomena. In this order the ducts of the generative organs open into the pallial chamber, and each individual, besides the essential organs of reproduction (testis or ovary), generally possesses an accessory gland; that of the female secreting a viscid material which unites the eggs together, whilst that of the male coats the spermatozoa, and aggregates them into peculiar worm-like filaments, termed 'spermatophores,' or the 'moving filaments of Needham.' The spermatophore is filled with spermatozoa, and possesses the power of expanding when moistened, rupturing, and expelling the contained spermatozoa with considerable force. During the congress of the sexes the male transfers the spermatophores to the pallial chamber of the female, true intromission not being possible. Further, in all the male Cuttle-fishes one of the arms is specially modified to subserve reproduction; being in many cases so altered as to become useless as a locomotive organ. The arm so affected in the more striking forms, is said to be 'hectocotylised' and—like the metamorphosed palpi of the male spiders—it serves to convey the seminal fluid to the female. The mode in which this is effected varies in different species. Thus, in the male *Octopus* (the Poulpe) the third right arm is primitively developed in a cyst, which ultimately ruptures and liberates the metamorphosed arm, which then appears to be of greater size than the corresponding arm on the left side, and to terminate in an oval plate (*fig.* 83). To this terminal plate the spermatophore is probably transmitted, but the arm itself remains permanently attached to the animal. In *Tremoctopus* the third right arm of the male is 'hectocotylised,' and is converted into a vermiform body, with two rows of ventral suckers, and an oval appendage or sac behind, which contains spermatozoa. Besides the suckers, the anterior part of the back is fringed with a number of so-called 'branchial' filaments.

In the *Argonaut* the male is not more than an inch in length, is devoid of a shell, and has its third left arm hectocotylised.

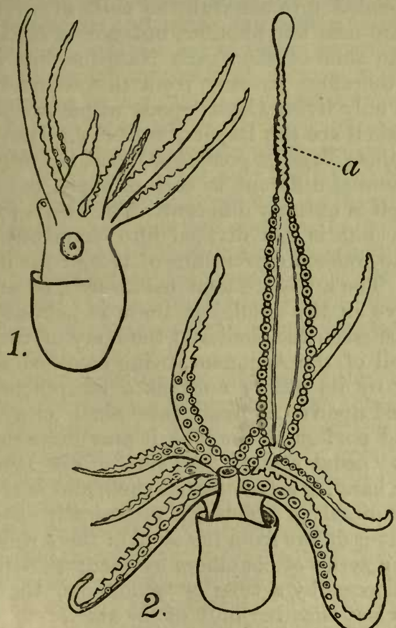

Fig. 83.—*Octopus carena* (male), showing cyst in place of the third arm. 2. Ventral side of an individual more developed, with the hectocotylus (*a*). (After Woodward.)

This arm is developed in a cyst, which is ruptured by the movements of the 'hectocotylus,' which then appears as a small worm-like body, with a filiform appendage in front, with two rows of alternating suckers, and a dorsal sac with numerous 'chromatophores.' The duct of the testis probably opens into the base of the hectocotylus, which is ultimately detached, and is deposited by the male within the pallial chamber of the female. When first discovered in this position, it was described as a parasitic worm under the name of 'Hectocotylus;' subsequently it was described as the entire male, and it is only recently that its true nature has been fully ascertained.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton is known as the 'cuttle-bone,' 'sepiostaire,' or 'pen' (*gladius*), and may be either corneous or calcareous. In some cases it is rendered complex by the addition of a chambered portion, or 'phragmacone,' which is to be regarded as a visceral skeleton, or 'splanchnoskeleton.' In *Spirula* the phragmacone is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, entirely from the *external* shell of the latter. The only living Cephalopods which are provided with an external shell are the Paper Nautilus (*Argonauta*), and the Pearly Nautilus (*Nautilus pompilius*); but not only is the structure of the animal different in each of these, but the nature of the shell itself is entirely different. The shell of the Argonaut is involuted, but is not divided into chambers, and it is secreted by the webbed extremities of two of the dorsal arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact, the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a 'nidamental shell,' or as it is secreted by a modified portion of the foot, it may more properly be regarded as a 'pedal shell.' The shell of the Pearly Nautilus, on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly partitions or septa, which are pierced by a tube or 'siphuncle,' the animal itself living in the last chamber only of the shell.

The *Cephalopoda* are divided into two extremely distinct and well marked orders, termed the *Dibranchiata*, and the *Tetrabranchiata*. The former is characterised by the possession of two branchiæ only, and comprises the Cuttle-fishes, Squids, and the Paper Nautilus. The latter is distinguished by the presence of four gills, and, though abundantly represented in past time, has no other living representative than the Pearly Nautilus alone.

CHAPTER LI.

DIVISIONS OF THE CEPHALOPODA.

ORDER I. DIBRANCHIATA.—The members of this order of the *Cephalapoda* are characterised as being swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube, and the shell is internal, or, if external, is not chambered.

The Cuttle-fishes are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size. They may be divided into two sections—*Octopoda* and *Decapoda*, according as they have simply eight arms, or eight arms and two additional 'tentacles.'

SECTION A. OCTOPODA.—The Cephalopods comprised in this section are distinguished by the possession of not more than eight arms, which are provided with sessile suckers. The shell is internal and rudimentary; in one instance only (the Argonaut), external.

This section comprises the two families of the *Argonautidæ*, and the *Octopodidæ*. In the former of these there is only the single genus *Argonauta* (the Paper Sailor, or the Paper Nautilus), of which the female and male differ greatly from one another. The female Argonaut (*fig.* 84) is protected by a thin *single-chambered* shell, in form symmetrical and involuted, which is secreted by the webbed extremities of the dorsal arms, but is not attached in any way to the body of the animal. It sits in its shell with the funnel turned toward the keel, and the webbed arms applied to the shell. The male Argonaut is much smaller than the female (about an inch in length), and is not protected by any shell. The third left arm is developed in a cyst, and ultimately becomes a 'hectocotylus,' and is deposited by the male in the pallial chamber of the female.

In the *Octopodidæ* (or Poulpes), there are eight arms, all similar to one another, and united at the base by a web. There is an internal rudimentary shell, represented by two short

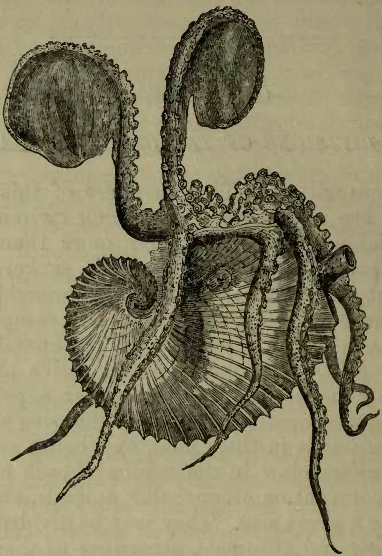

Fig. 84.—*Argonauta argo*, the 'Paper Nautilus,' female. The animal is represented in its shell, but the webbed dorsal arms are separated from the shell, which they ordinarily embrace.

styles encysted in the substance of the mantle.—(Owen.) The body is seldom provided with lateral fins. The third right arm of the male is primarily developed in a cyst, and ultimately becomes 'hectocotylised.'

SECTION B. DECAPODA.—The Cephalopods of this section have eight arms and two additional 'tentacles,' which are much longer than the true arms, and have expanded club-shaped extremities. The suckers are pedunculated; the body is always provided with lateral fins, and the shell is always internal (*fig.* 82).

This section comprises the three living families of the *Teuthidæ*, *Sepiadæ*, and the *Spirulidæ*, and the extinct family of the *Belemnitidæ*.

The family of the *Teuthidæ* comprises the Calamaries or Squids, characterised by the possession of an elongated body, with lateral fins. The shell is internal and horny, consisting of a median shaft and of two lateral wings; it is termed the 'gladius' or 'pen,' and in old specimens several may be found lodged in the mantle, one behind the other. In the common

Calamary (*Loligo*) the fourth left arm of the male is metamorphosed towards its extremity to subserve reproduction.

In the family of the *Sepiadæ* the internal shell is calcareous ('cuttle-bone' or 'sepiostaire') and is in the form of a broad plate, having an imperfectly chambered apex. In the living members of the family the body is provided with long lateral fins, sometimes as long and as wide as the body itself.

In the singular family of the *Spirulidæ* the internal skeleton is in the form of a nacreous, discoidal shell, the whorls of which are not in contact with one another, and which is divided into a series of chambers by means of partitions or septa which are pierced by a ventral tube or 'siphuncle.' The body is provided with minute terminal fins. The shell of the *Spirula*—commonly known as the 'post-horn'—is similar in structure to the shell of the *Nautilus*, but it is lodged in the posterior part of the body of the animal, and is, therefore, *internal*, whereas the shell of the latter is *external*. It really corresponds to the 'phragmacone' of the Belemnite. Though the shell occurs in enormous numbers in certain localities, a single perfect specimen of the animal is all that has been hitherto obtained.

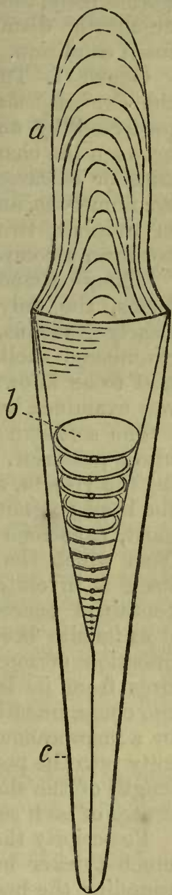

Fig. 85. — Diagram of Belemnite (after Professor Phillips). *a*. Horny pen or 'pro-ostracum.' *b*. Chambered 'phragmacone' in its cavity or 'alveolus.' *c*. 'Guard.'

In the extinct family of the *Belemnitidæ*, our knowledge is chiefly confined to the hard parts. Certain specimens, however, have been discovered which show that the *Belemnite* had essentially the structure of a Cuttle-fish, such as the recent *Sepia*. The body was provided with lateral fins; the arms were eight, furnished with horny hooks, with two 'tentacles;' and probably the mouth was provided with horny mandibles. An ink-bag was present. The internal skeleton of a *Belemnite* (*fig*. 85) consists of a chambered cone—the 'phragmacone'—the septa of which are pierced with a marginal tube, or 'siphuncle.' In the last chamber of the phragmacone is contained the ink-bag, often in a well preserved condition. Anteriorly the phragmacone is continued into a horny lamina, or 'pen' (the 'pro-ostracum' of Huxley), and posteriorly it is lodged in a conical sheath, or 'alveolus,' which is excavated in the substance of a nearly cylindrical, fibrous body, the 'guard,' which projects backwards for a longer or shorter distance, and is the part most usually found in a fossil condition.

Order II. Tetrabranchiata.—The members of this order of the *Cephalopoda* are characterised by being creeping animals, protected by an external, many-chambered shell, the septa between the chambers of which are perforated by a membranous or calcareous tube, termed the 'siphuncle.' The arms are numerous, and are devoid of suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.

Though abundantly represented by many and varied extinct forms, the only living member of the *Tetrabranchiata* is the Pearly Nautilus, which has been long known by its beautiful chambered shell, but the soft parts of which can hardly be said to be known by more than one perfect specimen, which was examined by Professor Owen.

The soft structures in the Pearly Nautilus may be divided into a posterior, soft, membranous mass (*metasoma*), containing the viscera, and an anterior muscular division, comprising the head (*prosoma*); the whole being contained in the outermost, capacious chamber (the body-chamber) of the shell, from which the head can be protruded at will. The shell itself is involuted, and many-chambered, the animal being contained successively in each chamber, and retiring from it as its size becomes sufficiently great to necessitate the acquisition of more room. Each chamber, as the animal retires from it, is walled off by a curved, nacreous septum; the communication between the chambers being still kept up by a membranous tube or siphuncle, which opens at one extremity into the pericardium, and is continued through the entire length of the shell. The position of the siphuncle is in the centre of each septum.

Posteriorly the mantle of the Nautilus is very thin, but it is much thicker in front, and forms a thick fold or collar, surrounding the head and its appendages. From the sides of the head spring a great number of muscular prehensile processes, or 'arms,' which are annulated, but are not provided with cups or suckers. In the centre of the head is the mouth, surrounded by a circular fleshy lip, external to which is a series of labial processes. The mouth opens into a buccal cavity, armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak of a parrot, except that the under mandible is the longest. There is also a 'tongue,' which is fleshy and sentient in front, but is armed with recurved teeth behind. The gullet opens into a large crop, which in turn conducts to a gizzard, and the intestine terminates at the base of the funnel. On each side of the crop is a well developed liver.

The heart is contained in a large cavity, divided into several chambers, and termed the 'pericardium.'—(Owen.) The respiratory organs are in the form of four pyramidal branchiæ, two on each side.

The chief masses of the nervous system are the cerebral and infra-œsophageal ganglia, which are partially protected by a cartilaginous plate, which is to be regarded as a rudimentary cranium, and which sends out processes for the attachment of muscles. The organs of sense are two large eyes, attached by short stalks to the sides of the head, and two hollow plicated subocular processes, believed to be olfactory in their function.

The reproductive organs of the female consist of an ovary, oviduct, and accessory nidamental gland.

There is no ink-bag, and the funnel does not form a complete tube, but consists of two muscular lobes, which are simply in apposition. It is the organ by which swimming is effected, the animal being propelled through the water by means of the reaction produced by the successive jets emitted from the funnel. The function of the chambers of the shell appears to be that of reducing the specific gravity of the animal to near that of the surrounding water; since they are most probably filled with some gas, secreted by the animal. The function of the siphuncle is unknown, except in so far as it doubtless serves to maintain the vitality of the shell.

SHELL OF THE TETRABRANCHIATA.—The shells of all the *Tetrabranchiata* agree in the following points:—

1. The shell is external.
2. The shell is divided into a series of chambers by plates or 'septa,' the edges of which, where they appear on the shell, are termed the 'sutures.'
3. The outermost chamber of the shell is the largest, and is the one inhabited by the animal.
4. The various chambers of the shell are united by a tube, termed the 'siphuncle.'

Agreeing in all these fundamental points of structure, two very distinct types of shell may be distinguished as characteristic of the two families *Nautilidæ* and *Ammonitidæ*, into which the order *Tetrabranchiata* is divided.

In the family *Nautilidæ* (*fig.* 86), the 'septa' of the shell are simple, curved, or slightly lobed; the 'sutures' are more or less completely plain; and the 'siphuncle' is central, subcentral, or internal (i.e. on the *concave* side of the curved shells).

In the family *Ammonitidæ* (*fig.* 86), on the other hand, the septa are folded and complex; the sutures are angulated, zigzag, lobed, or foliaceous; and the siphuncle is external (i.e. on the *convex* side of the curved shells).

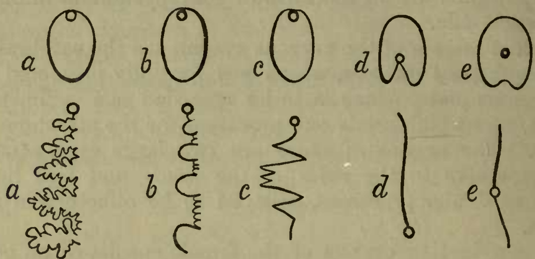

Fig. 86.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopoda. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a a. Ammonite* or *Baculite*; *b b. Ceratite*; *c c. Goniatite*; *d d. Clymenia*; *e e. Nautilus* or *Orthoceras.*

In both these great *types* of shell, a series of representative *forms* exists, resembling each other in the manner in which the shell is folded or coiled, but differing in their fundamental structure. All these different forms may be looked upon as produced by the modification of a greatly elongated cone, the structure of which may be in conformity with the type either of the *Nautilidæ*, or of the *Ammonitidæ*. The following table (after Woodward) exhibits the representative forms in the two families:—

	Nautilidæ.	*Ammonitidæ.*
Shell straight	Orthoceras . . .	Baculites.
,, bent on itself	Ascoceras	Ptychoceras.
,, curved	Cyrtoceras . . .	Toxoceras.
,, spiral	Trochoceras . .	Turrilites.
,, discoidal	Gyroceras	Crioceras.
,, discoidal and produced	Lituites	Ancyloceras.
,, involute	Nautilus	Ammonites.

After the *Nautilus* itself, the most important form of the *Nautilidæ* is the *Orthoceras.* In structure this was doubtless essentially identical with the Nautilus, but the shell, instead of being coiled into a spiral lying in one plane, was extended in a straight, or nearly straight, line. Orthoceratites of more than six feet in length have been discovered, but in all, the body-chamber, in which the animal was lodged, appears to have been comparatively small. The siphuncle is usually very complex in structure, and was calcareous throughout its entire length.

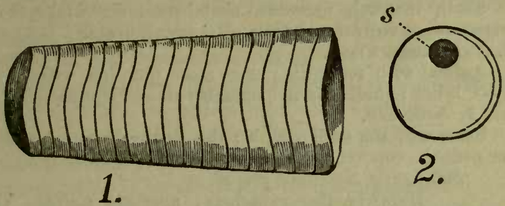

Fig. 87.—*Orthoceras explorator*, Billings. 1. Side view of a fragment, showing the septa. 2. Transverse section of the same showing (*s*) the siphuncle.

The simplest form of the *Ammonitidæ* is the *Baculite*, in which the shell is straight, like that of an *Orthoceras*, whilst the septa have the characters of those of an *Ammonite*, and the siphuncle is external. In the *Turrilite* the structure of the shell is the same, but it is coiled into a spiral. In the *Ammonite* itself, the shell is discoidal and involuted, corresponding (in *form*) to the shell of the *Nautilus*; the body-chamber was of comparatively large size, and had its aperture closed, in some species at any rate, by an operculum.

SYNOPSIS OF THE FAMILIES OF THE CEPHALOPODA.

Class Cephalopoda.

Order I. Dibranchiata.

Animal with two branchiæ; not more than eight or ten arms, provided with suckers; an ink-bag; shell commonly internal and rudimentary; rarely external, but not chambered.

Section A. Octopoda.

Arms eight, suckers sessile.

Fam. 1. *Argonautidæ.*

Female provided with a calcareous, external, monothalamous shell, secreted by the webbed extremities of the dorsal arms. Gen. *Argonauta.*

Fam. 2. *Octopodidæ.*

Shell internal, rudimentary, uncalcified. No pallial fins in most. Ill. Gen. *Octopus, Tremoctopus, Eledone, Pinnoctopus.*

Section B. Decapoda.

Arms eight, with two clavate 'tentacles;' suckers pedunculated.

Fam. 3. *Teuthidæ.*

Shell an internal horny 'pen' or 'gladius.' Fins mostly terminal. Ill. Gen. *Loligo, Onychoteuthis, Ommastrephes.*

Fam. 4. *Belemnitidæ.*

Shell internal, composed of a conical chambered portion ('phragmacone') with a marginal siphuncle, sometimes produced into a horny plate or 'pen,' and lodged in a cylindrical fibrous 'guard.' Ill. Gen. *Belemnites, Belemnitella, Belemniteuthis.*

Fam. 5. *Sepiadæ.*

Shell calcareous, consisting of a broad, laminar plate, terminating posteriorly in an imperfectly chambered apex ('phragmacone'). Ill. Gen. *Sepia, Beloptera, Spirulirostra.*

Fam. 6. *Spirulidæ.*

Shell, internal, nacreous, chambered, discoidal; the whorls separate; a ventral siphuncle. Genus. *Spirula.*

ORDER II. TETRABRANCHIATA.

Animal with four gills; arms more than ten, without suckers; no ink-bag; shell external, chambered, and siphuncled.

Fam. 1. *Nautilidæ.*

Sutures of the shell simple; the siphuncle central, subcentral, or near the concavity of the curved shells, simple.

Sub-family Nautilidæ proper.

Body-chamber capacious; aperture simple; siphuncle central or internal. Ill. Gen. *Nautilus. Lituites, Trochoceras.*

Sub-family Orthoceratidæ.

Shell straight, curved, or discoidal; body-chamber small; aperture contracted; siphuncle complicated. Ill. Gen. *Orthoceras, Phragmoceras, Cyrtoceras.*

Fam. 2. *Ammonitidæ.*

Shell discoidal, curved, spiral, or straight; body-chamber elongated; aperture guarded by processes, or closed by an operculum; sutures angulated, lobed, or foliaceous; siphuncle external or dorsal (on the convex side of the curved shells). Ill. Gen. *Ammonites, Ceratites, Baculites, Turrilites, Scaphites, Ancyloceras.*

CHAPTER LII.

DISTRIBUTION OF THE MOLLUSCA PROPER IN TIME.

REMAINS of the *Mollusca* proper are found in greater or less abundance in almost all the stratified rocks from the commencement of the Silurian period up to the present day. Speaking generally, the Tetrabranchiate *Cephalopoda* are the chief representatives of the *Mollusca* in the Palæozoic Rocks, the *Lamellibranchiata* and the Dibranchiate *Cephalopoda* in the Mesozoic Rocks, and the *Gasteropoda* in the Kainozoic period; but all the primary classes are represented even in the Lower Silurian Rocks. The following are the more noticeable facts relating to the distribution of the various classes in past time.

Lamellibranchiata.—The Lamellibranchs are known to have existed in the Lower Silurian period, and have steadily increased up to the present day, when the class appears to have attained its maximum, both as regards numbers and as regards variety of type. The recent bivalves are, also, superior in organisation to those which have preceded them. Upon the whole, the Asiphonate bivalves are more characteristically Palæozoic, whilst those in which the mantle-lobes are united, and there are respiratory siphons, are chiefly found in the Secondary and Tertiary epochs. One very singular and aberrant family, viz. the *Hippuritidæ*, is exclusively confined to the Secondary Rocks, and is, indeed, not known to occur beyond the limits of the Cretaceous formation. The *Veneridæ*, which are perhaps the most highly organised of the families of the *Lamellibranchiata*, appeared for the first time in the Oolitic Rocks, and, increasing in the Tertiary period, have culminated in the Recent period.

Gasteropoda.—The *Gasteropoda* are represented in past time from the Lower Silurian Rocks up to the present day. Of the *Branchifera* the *Holostomata* are more abundant in the Palæozoic period, the *Siphonostomata* abounding more in the Secondary and Tertiary Rocks, but not attaining their maximum till the present day. The place of the carnivorous *Siphonostomata* in the Palæozoic seas appears to have been filled by the Tetrabranchiate Cephalopods.

The *Heteropoda* are, likewise, of very ancient origin, having commenced their existence in the lowest Silurian deposits. The genera *Bellerophon*, *Porcellia*, *Cyrtolites*, and *Maclurea* are almost exclusively Palæozoic; *Bellerophina* is found in the Gault (Secondary), and *Carinaria* has been detected in the Tertiaries.

The Pulmonate *Gasteropoda*, as was to be anticipated, are not found abundantly as fossils, occurring chiefly in lacustrine and estuarine deposits, in which the genera *Limnæa*, *Paludina*, *Valvata*, *Ancylus*, &c., are amongst those most commonly represented. These, however, are entirely Mesozoic and Kainozoic. In the Palæozoic period the sole known representatives of the *Pulmonifera* are the *Pupa vetusta* and *Zonites priscus* of the Carboniferous Rocks.

Pteropoda.—The Pteropods are not largely represented in fossiliferous deposits, but they have a wide range in time, extending from the Lower Silurian Rocks up to the present day. The *Theca* and *Conularia* of the Palæozoic period, if truly Pteropods, are of comparatively gigantic size, and extend from the Lower Silurian to the Carboniferous period. The Silurian fossil, *Tentaculites*, is asserted by M. Barrande to be a Pteropod, but it is usually looked upon as a tubicolous Annelide. The recent genus *Hyalea* is represented in the Tertiary period (Miocene).

Cephalopoda.—The Cephalopods are largely represented in all the primary groups of stratified rocks from the Lower Silurian up to the present day. Of the two orders of *Cepha-*

lopoda, the *Tetrabranchiata* is the oldest, attaining its maximum in the Palæozoic period, decreasing in the Mesozoic and Kainozoic epochs, and being represented at the present day by the single form *Nautilus pompilius*. Of the sections of this order, the *Nautilidæ* proper and the *Orthoceratidæ* are pre-eminently Palæozoic, and the *Ammonitidæ* is not only pre-eminently but is almost exclusively Secondary. Of the abundance of the two former families in the Silurian seas some idea may be obtained, when it is mentioned that about a thousand species have been described by M. Barrande from the Silurian basin of Bohemia alone. The *Nautilidæ* proper have gradually decreased in numbers from the Palæozoic, through the Secondary and Tertiary periods to the present day. The *Orthoceratidæ* died out much sooner, being exclusively Palæozoic, with the exception of the genera *Orthoceras* itself and *Cyrtoceras*, which survived into the commencement of the Secondary period, finally dying out in the Trias.

The second family of the *Tetrabranchiata*, viz. the *Ammonitidæ*, is almost exclusively Secondary, being very largely represented by numerous species of the genera *Ammonites*, *Ceratites*, *Baculites*, *Turrilites*, &c. The only Palæozoic genera are *Goniatites* and *Bactrites*, of which the former is found from the Upper Silurian to the Trias, whilst the latter is a Devonian form. The genus *Ceratites* is characteristically Triassic, but it is said to occur in the Devonian Rocks. All the remaining genera are exclusively Secondary, the genera *Baculites*, *Turrilites*, *Hamites*, and *Ptychoceras* being confined to the Cretaceous period.

Of the Dibranchiate Cephalopoda the record is less perfect, as they have few structures which are capable of preservation. They attain their maximum, as fossils, shortly after their first appearance in the Secondary Rocks, where they are represented by the large and important family of the *Belemnitidæ*. Some of the *Teuthidæ* and *Sepiadæ* are found both in the Secondary and in the Tertiary Rocks, and two species of Argonaut have been discovered in the Later Tertiaries. No example of a Dibranchiate Cephalopod is known from the Palæozoic deposits, and the order attains its maximum at the present day.

TABULAR VIEW OF THE CHIEF SUBDIVISIONS OF THE INVERTEBRATA.

SUB-KINGDOM I.—PROTOZOA.

CLASS I. GREGARINIDÆ.
CLASS II. RHIZOPODA.
  Order 1. Amœbea.
    2. Foraminifera.
    3. Radiolaria.
    4. Spongida.
CLASS III. INFUSORIA.
  Order 1. Suctoria.
    2. Ciliata.
    3. Flagellata.

SUB-KINGDOM II.—CŒLENTERATA.

CLASS I. HYDROZOA.
  Sub-class A. *Hydroida.*
    Order 1. Hydrida.
      2. Corynida.
      3. Sertularida.
      4. Campanularida.
  Sub-class B. *Siphonophora.*
    Order 5. Calycophoridæ.
      6. Physophoridæ.
  Sub-class C. *Discophora.*
    Order 7. Medusidæ.
  Sub-class D. *Lucernarida.*
    Order 8. Lucernariadæ.
      9. Pelagidæ.
      10. Rhizostomidæ.
  Sub-class E. *Graptolitidæ.*
CLASS II. ACTINOZOA.
  Order 1. Zoantharia.
    Sub-order *a.* Z. Malacodermata.
      b. Z. Sclerobasica.
      c. Z. Sclerodermata.
  Order 2. Alcyonaria.
    Fam. *a.* Alcyonidæ.
      b. Tubiporidæ.
      c. Pennatulidæ.
      d. Gorgonidæ.
  Order 3. Rugosa.

Order 4. Ctenophora.
Sub-order *a*. Stenostomata.
b. Eurystomata.

SUB-KINGDOM III.—ANNULOIDA.

Class I. Echinodermata.
Order 1. Cystoidea.
2. Blastoidea.
3. Crinoidea.
4. Echinoidea.
5. Asteroidea.
6. Ophiuroidea.
7. Holothuroidea.

Class II. Scolecida.
Division A. *Platyelmia.*
Order 1. Tæniada.
2. Trematoda.
3. Turbellaria.
Sub-order *a*. Planarida.
b. Nemertida.
Division B. *Nematelmia.*
Order 4. Acanthocephala.
5. Gordiacea.
6. Nematoda.
Division C. *Rotifera.*
Order. Rotifera.

SUB-KINGDOM IV.—ANNULOSA.

Division A. Anarthropoda.
Class I. Gephyrea.
Class II. Annelida.
Order. Hirudinea, Oligochæta — Abranchiata.
Tubicola, Errantia. — Branchiata.
Class III. Chætognatha.

Division B. Arthropoda, or Articulata.
Class I. Crustacea.
Sub-class I. *Epizoa.*
Order 1. Ichthyophthira.
Sub-class II. *Cirripedia.*
Order 2. Thoracica — Balanidæ. Verrucidæ. Lepadidæ.
3. Abdominalia.
4. Apoda.

Sub-class III. *Entomostraca.*

Order 5. Ostracoda } Legion Lophyropoda.
6. Copepoda }
7. Cladocera } Legion Branchiopoda.
8. Phyllopoda }
9. Trilobita. }
10. Merostomata.
Sub-order *a.* Xiphosura.
b. Eurypterida.

Sub-class IV. *Malacostraca.*

Order 11. Læmodipoda } Division A. Edriophthalmata.
12. Isopoda }
13. Amphipoda }
14. Stomapoda } Division B. Podophthalmata.
15. Decapoda }
Tribe *a.* Macrura.
b. Anomura.
c. Brachyura.

CLASS II. ARACHNIDA.

Division A. *Trachearia.*

Order 1. Podosomata.
2 Acarina.
3. Adelarthrosomata.

Division B. *Pulmonaria.*

Order 4. Pedipalpi.
5. Araneida.

CLASS III. MYRIAPODA.

Order 1. Chilopoda.
2. Chilognatha.

CLASS IV. INSECTA.

Sub-class I. *Ametabola.*

Order 1. Anoplura.
2. Mallophaga.
3. Thysanura.

Sub-class II. *Hemimetabola.*

Order 4. Hemiptera.
5. Orthoptera.
6. Neuroptera.

Sub-class III. *Holometabola.*

Order 7. Aphaniptera.
8. Diptera.
9. Lepidoptera.
10. Hymenoptera.
11. Strepsiptera.
12. Coleoptera.

SUB-KINGDOM V.—MOLLUSCA.

DIVISION A. MOLLUSCOIDA.
Class I. *Polyzoa.*
Order 1. Phylactolæmata.
2. Gymnolæmata.
Class II. *Tunicata.*
Order 1. Ascidia branchialia.
2. Ascidia abdominalia.
3. Ascidia larvalia.
Class III. *Brachiopoda.*

DIVISION B. MOLLUSCA PROPER.
Class IV. *Lamellibranchiata.*
Section *a.* Asiphonida.
b. Siphonida.
Class V. *Gasteropoda.*
Sub-class I. *Branchifera.*
Order 1. Prosobranchiata.
Section *a.* Siphonostomata.
b. Holostomata.
Order 2. Opisthobranchiata.
Section *a.* Tectibranchiata.
b. Nudibranchiata.
Order 3. Nucleobranchiata (Heteropoda).
Fam. *a.* Firolidæ.
b. Atlantidæ.
Sub-class II. *Pulmonifera.*
Section *a.* Inoperculata.
b. Operculata.
Class VI. *Pteropoda.*
Order 1. Thecosomata.
2. Gymnosomata.
Class VII. *Cephalopoda.*
Order 1. Tetrabranchiata.
2. Dibranchiata.

GLOSSARY.

ABDOMEN (Lat. *abdo*, I conceal). The posterior cavity of the body, containing the intestines and others of the viscera. In many Invertebrates there is no separation of the body-cavity into thorax and abdomen, and it is only in the higher *Annulosa* that a distinct abdomen can be said to exist.

ABERRANT (Lat. *aberro*, I wander away). Departing from the regular type.

ABNORMAL (Lat. *ab*, from; *norma*, a rule). Irregular; deviating from the ordinary standard.

ABRANCHIATE (Gr. *a*, without; *bragchia*, gills). Destitute of gills or branchiæ.

ACALEPHÆ (Gr. *akalephe*, a nettle). Applied formerly to the Jelly-fishes or Sea-nettles, and other Radiate animals, in consequence of their power of stinging, derived from the presence of microscopic cells, called 'thread-cells,' in the integument.

ACANTHOCEPHALA (Gr. *akantha*, a thorn; *kephale*, head). A class of parasitic worms, in which the head is armed with spines.

ACANTHOMETRINA (Gr. *akantha*; and *metra*, the womb). A family of *Protozoa*, characterised by having radiating siliceous spines.

ACARINA (Gr. *akari*, a mite). A division of the *Arachnida*, of which the Cheese-mite is the type.

ACEPHALOUS (Gr. *a*, without; *kephale*, the head). Not possessing a distinct head.

ACETABULA (Lat. *acetabulum*, a cup). The suckers with which the cephalic processes of many *Cephalopoda* (Cuttle-fishes) are provided.

ACRITA (Gr. *akritos*, confused). A term sometimes employed as synonymous with *Protozoa*, or the lowest division of the animal kingdom.

ACTINOMERES (Gr. *aktin*, a ray; *meros*, a part). The lobes which are mapped out on the surface of the body of the *Ctenophora*, by the ctenophores, or comb-like rows of cilia.

ACTINOSOMA (Gr. *aktin*; and *soma*, body). Employed to designate the entire body of any *Actinozoön*, whether this be simple (as in the Sea-Anemones), or composed of several zoöids (as in most Corals).

ACTINOZOA (Gr. *aktin*; and *zoön*, an animal). That division of the *Cœlenterata*, of which the Sea-Anemones may be taken as the type.

ADELARTHROSOMATA (Gr. *adelos*, hidden; *arthros*, joint; *soma*, body). An order of the *Arachnida*.

AGAMIC (Gr. *a*, without; *gamos*, marriage). Applied to all forms of reproduction in which the sexes are not directly concerned.

AMBULACRA (Lat. *ambulacrum*, a place for walking). The perforated spaces through which are protruded the tube-feet, by means of which locomotion is effected in the *Echinodermata*.

AMBULATORY (Lat. *ambulo*, I walk). Formed for walking. Applied to a single limb, or to an entire animal.

AMETABOLIC (Gr. *a*, without; *metabole*, change). Applied to those insects which do not possess wings when perfect, and do not, therefore, pass through any marked metamorphosis.

AMŒBA (Gr. *amoibos*, changing). A species of *Rhizopod*, so called from the numerous changes of form which it undergoes.

Amœbiform. Resembling an *Amœba* in form.

Amorphozoa (Gr. *a*, without; *morphe*, shape; *zoön*, animal). A name sometimes used to designate the *Sponges*.

Amphidiscs (Gr. *amphi*, at both ends; *diskos*, a quoit, or round plate). The spicula which surround the gemmules of *Spongilla*, and resemble two toothed wheels united by an axle.

Amphipoda (Gr. *amphi*, and *pous*, a foot). An order of *Crustacea*.

Analogous. Applied to parts which perform the same function.

Anarthropoda (Gr. *a*, without; *arthros*, a joint; and *pous*, foot). That division of *Annulose* animals in which there are no articulated appendages.

Androgynous (Gr. *anēr*, a man; *gune*, a woman). Synonymous with hermaphrodite, and implying that the two sexes are united in the same individual.

Androphores (Gr. *anēr*, a man; and *phero*, I carry). Applied to medusiform gonophores of the *Hydrozoa*, which carry the spermatozoa, and differ in form from those in which the ova are developed.

Annelida (a Gallicised form of *Annulata*). The Ringed Worms, which form one of the divisions of the *Anarthropoda*.

Annulated. Composed of a succession of rings.

Annuloida (Lat. *annulus*, a ring; Gr. *eidos*, form). The sub-kingdom comprising the *Echinodermata* and the *Scolecida* (= *Echinozoa*).

Annulosa (Lat. *annulus*). The sub-kingdom comprising the *Anarthropoda* and the *Arthropoda* or *Articulata*, in all of which the body is more or less evidently composed of a succession of rings.

Anomura (Gr. *anomos*, irregular; *oura*, tail). A tribe of Decapod *Crustacea*, of which the Hermit Crab is the type.

Anoplura (Gr. *anoplos*, unarmed; *oura*, tail). An order of Apterous Insects.

Antennæ (Lat. *antenna*, a yard-arm). The jointed horns or feelers, possessed by the majority of the *Articulata*.

Antennules (diminutive of *antennæ*). Applied to the smaller pair of antennæ in the *Crustacea*.

Antlia (Lat. *antlia*, a pump). The spiral trunk or proboscis with which Butterflies and other Lepidopterous insects suck up the juices of flowers.

Aphaniptera (Gr. *aphanos*, inconspicuous; and *pteron*, a wing). An order of Insects, comprising the Fleas.

Apodal (Gr. *a*, without; *pous*, foot). Devoid of feet.

Apodemata (Gr. *apodaio*, I portion off). Applied to certain chitinous septa which divide the tissues in *Crustacea*.

Aptera (Gr. *a*, without; *pteron*, wing). A division of Insects, which is characterised by the absence of wings in the adult condition.

Apterous. Devoid of wings.

Arachnida (Gr. *arachne*, a spider). A class of the *Articulata*, comprising Spiders, Scorpions, and allied animals.

Arborescent. Branched like a tree.

Arenaceous. Sandy, or composed of grains of sand.

Articulata (Lat. *articulus*, a joint). A division of the animal kingdom, comprising Insects, Centipedes, Spiders, and Crustaceans, characterised by the possession of jointed bodies or jointed limbs. The term *Arthropoda* is now more usually employed.

Ascidioida (Gr. *askos*, a bottle; *eidos*, form). A synonym of *Tunicata*, a class of Molluscous Animals, which have the shape, in many cases, of a two-necked bottle.

Asexual. Applied to modes of reproduction in which the sexes are not concerned.

ASIPHONATE. Not possessing a respiratory tube or siphon. (Applied to a division of the *Lamellibranchiate* Molluscs.)

ASTEROID (Gr. *aster*, a star; and *eidos*, form). Star-shaped; or possessing radiating lobes or rays like a star-fish.

ASTEROIDA. An order of *Echinodermata*, comprising the Star-fishes, characterised by their rayed form.

ASTOMATOUS (Gr. *a*, without; *stoma*, mouth). Not possessing a mouth.

AURELIA (Lat. *aurum*, gold). Applied to the chrysalides of some *Lepidoptera*, on account of their exhibiting a golden lustre.

AVICULARIUM (Lat. *avicula*, diminutive of *avis*, a bird). A singular appendage, often shaped like the head of a bird, found in many of the *Polyzoa*.

AZYGOS (Gr. *a*, without; *zugos*, yoke). Single, without a fellow.

BACTERIUM (Gr. *bakterion*, a staff). A kind of staff-shaped filament which appears in organic infusions after they have been exposed to the air.

BALANIDÆ (Gr. *balanos*, an acorn). A family of sessile *Cirripides*, commonly called 'Acorn-shells.'

BIFID. Cleft into two parts, forked.

BILATERAL. Having two symmetrical sides.

BIRAMOUS (Lat. *bis*, twice; *ramus*, a branch). Applied to a limb, which is divided into two oar-like extremities (e.g. the limbs of Cirripides).

BIVALVE (Lat. *bis*, twice; *valvæ*, folding-doors). Composed of two plates or valves; applied to the shell of the *Lamellibranchiata* and *Brachiopoda*, and to the carapace of certain *Crustacea*.

BLASTOIDEA (Gr. *blastos*, a bud; and *eidos*, form). An extinct order of *Echinodermata*, often called *Pentremites*.

BRACHIOPODA (Gr. *brachion*, an arm; *pous*, the foot). A class of the *Molluscoida*, often called 'Lamp Shells,' characterised by possessing two fleshy arms continued from the sides of the mouth.

BRACHYURA (Gr. *brachus*, short; *oura*, tail). A tribe of the Decapod *Crustacea*, with short tails (i.e. the Crabs).

BRACTS. (*See* Hydrophyllia.)

BRANCHIA (Gr. *bragchia*, the gill of a fish). A respiratory organ adapted to breathe air dissolved in water.

BRANCHIATE. Possessing gills or branchiæ.

BRANCHIFERA (Gr. *bragchia*, gill; and *phero*, I carry). A division of *Gasteropodous Molluscs*, in which the respiration is aquatic, and the respiratory organs are mostly in the form of distinct gills.

BRANCHIO-GASTEROPODA (= Branchifera).

BRANCHIOPODA (Gr. *bragchia*, and *pous*, foot). A legion of *Crustacea*, in which the gills are supported by the feet.

BRYOZOA (Gr. *bruon*, moss; *zoön*, animal). A synonym of *Polyzoa*, a class of the *Molluscoida*.

BUCCAL (Lat. *bucca*, mouth or cheeks). Connected with the mouth.

BURSIFORM (Lat. *bursa*, a purse; *forma*, shape). Shaped like a purse, subspherical.

BYSSIFEROUS. Producing a byssus.

BYSSUS. A term applied to the silky filaments by which the *Pinna*, the common Mussel, and certain other bivalve *Mollusca* attach themselves to foreign objects.

CÆCAL (Lat. *cæcus*, blind). Terminating blindly, or in a closed extremity.

CÆCUM (Lat. *cæcus*). A tube which terminates blindly,

CÆSPITOSE (Lat. *cæspes*, a turf). Tufted.

Cainozoic. (*See* Kainozoic.)

Calcareous (Lat. *calx*, lime). Composed of carbonate of lime.

Calice. The little cup in which the polype of a coralligenous Zoophyte (*Actinozoön*) is contained.

Calycophoridæ (Gr. *kalux*, a cup; and *phero*, I carry). An order of the Oceanic *Hydrozoa*, so called from their possessing bell-shaped swimming organs (*nectocalyces*).

Calyx (Lat. *calyx*, a cup). Applied to the cup-shaped body of *Vorticella* (*Protozoa*), or of a *Crinoid* (*Echinodermata*).

Campanularida (Lat. *campanula*, a bell). An order of Hydroid Zoophytes.

Capitulum (Lat. diminutive of *caput*, head). Applied to the body of a Barnacle (*Lepadidæ*), from its being supported upon a stalk or peduncle.

Carapace. A protective shield. Applied to the upper shell of Crabs, Lobsters, and many other *Crustacea*; also to the case with which certain of the *Infusoria* are provided.

Carnivorous (Lat. *caro*, flesh; *voro*, I devour). Feeding upon flesh.

Carnose (Lat. *caro*). Fleshy.

Caudal (Lat. *cauda*, the tail). Belonging to the tail.

Cephalic (Gr. *kephale*, head). Belonging to the head.

Cephalo-branchiate (Gr. *kephale*; and *bragchia*, gill). Carrying gills upon the head. Applied to a section of the *Annelida*, which, like the *Serpulæ*, have tufts of external gills placed upon the head.

Cephalophora (Gr. *kephale*; and *phero*, I carry). Used synonymously with *Encephala*, to designate those *Mollusca* which possess a distinct head.

Cephalopoda (Gr. *kephale*; and *poda*, feet). A class of the *Mollusca*, comprising the Cuttle-fishes and their allies, in which there is a series of arms ranged round the head.

Cephalothorax (Gr. *kephale*; and *thorax*, chest). The anterior division of the body in many *Crustacea* and *Arachnida*, which is composed of the coalesced head and chest.

Cestoidea (Gr. *kestos*, a girdle). An old name for the *Tæniada*, a class of Intestinal Worms, with flat bodies like tape (hence the name Tapeworms).

Chelæ (Gr. *chele*, a claw). The prehensile claws with which some of the limbs are terminated in certain *Crustacea*, such as the Crab, Lobster, &c.

Chelate. Possessing chelæ; applied to a limb.

Chelicerræ (Gr. *chele*, a claw; and *keras*, a horn). The prehensile claws of the Scorpion, supposed to be homologous with antennæ.

Chilognatha (Gr. *cheilos*, a lip; and *gnathos*, a jaw). An order of the *Myriapoda*

Chilopoda (Gr. *cheilos*; and *poda*, feet). An order of the *Myriapoda*.

Chitine (Gr. *chiton*, a coat). The peculiar chemical principle, nearly allied to horn, which forms the exoskeleton in many Invertebrate Animals, especially in the *Arthropoda* (*Crustacea*, *Insecta*, &c.).

Chlorophyll (Gr. *chloros*, green; and *phyllos*, a leaf). The green colouring matter of plants.

Chromatophores (Gr. *chroma*, complexion, or colour; and *phero*, I carry). Little sacs which contain pigment-granules, and are found in the integument of Cuttle-fishes.

Chrysalis (Gr. *chrusos*, gold). The motionless pupa of butterflies and moths, so called because sometimes exhibiting a golden lustre.

Chylaqueous fluid. A fluid consisting partly of water derived from the exterior, and partly of the products of digestion (chyle), occupying the body-cavity or perivisceral space in many Invertebrates (*Annelides*, *Echinoderms*, &c.), and sometimes having a special canal-system for its conduction (chylaqueous canals).

CHYLIFIC (Gr. *chulos*, juice [chyle]; and Lat. *facio*, I make). Producing chyle. Applied to one of the stomachs, when more than one is present. The word is of mongrel origin; and 'chylopoietic' is more correct.

CHYME-MASS. The central, semi-fluid sarcode in the interior of an *Infusorian*.

CILIA (Lat. *cilium*, an eye-lash). Microscopic, hair-like filaments, which have the power of lashing backwards and forwards, thus creating currents in the surrounding or contiguous fluid, or subserving locomotion in the animal which possesses them.

CILIOGRADA (Lat. *cilium*; and *gradior*, I walk). Synonymous with *Ctenophora*, an order of *Actinozoa*.

CINCLIDES (Gr. *kigklis*, a lattice). Special apertures in the column-walls of Sea-anemones (*Actiniæ*), which probably serve for the emission of the cord-like 'craspeda.'

CIRRI (Lat. *cirrus*, a curl). Tendril-like appendages, such as the feet of Barnacles and Acorn-shells (*Cirripedes*), the lateral processes on the arms of *Brachiopoda*, &c.

CIRRIFEROUS or CIRRIGEROUS. Carrying cirri.

CIRRIPEDIA, CIRRHIPEDIA, or CIRRHOPODA (Lat. *cirrus*, a curl; and *pes*, a foot). A sub-class of *Crustacea* with curled jointed feet.

CLADOCERA (Gr. *klados*, a branch, *keras*, a horn). An order of *Crustacea* with branched antennæ.

CLAVATE (Lat. *clavus*, a club). Club-shaped.

CLOACA (Lat. a sink). The cavity into which the intestinal canal and the ducts of the generative and urinary organs open in common, in some Invertebrates (e.g. in Insects).

CLYPEIFORM (Lat. *clypeus*, a shield; and *forma*, shape). Shield-shaped; applied, for example, to the carapace of the King-crab.

CNIDÆ (Gr. *knide*, a nettle). The urticating cells, or 'thread-cells,' whereby many *Cœlenterate* animals obtain their power of stinging.

COCCOLITHS (Gr. *kokkos*, a berry; *lithos*, stone). Minute oval or rounded bodies, which are found either free or attached to the surface of coccospheres.

COCCOSPHERES (Gr. *kokkos*; and *sphaira*, a sphere). Spherical masses of sarcode, enclosed in a delicate calcareous envelope, and bearing coccoliths upon their external surface. Both coccospheres and coccoliths are imbedded in a diffused plasmodium of sarcode, the whole constituting a low *Rhizopodic* organism.

COCOON (French *cocon*, the cocoon of the silk-worm; connected with Fr. *coque*, shell, which is derived from the Lat. *concha*). The outer covering of silky hairs with which the pupa or chrysalis of many insects is protected.

CODONOSTOMA (Gr. *kodon*, a bell; *stoma*, mouth). The aperture or mouth of the disc (nectocalyx) of a *Medusa* or of the bell (gonocalyx) of a medusiform gonophore.

CŒLENTERATA (Gr. *koilos*, hollow; *enteron*, the bowel). The sub-kingdom which comprises the *Hydrozoa* and *Actinozoa*. Proposed by Frey and Leuckhart in place of the old term *Radiata*, which included other animals as well.

CŒNENCHYMA (Gr. *koinos*, common; *enchuma*, tissue). The common calcareous tissue which unites together the various corallites of a compound corallum.

CŒNŒCIUM (Gr. *koinos*, common; *oikos*, house). The entire dermal system of any *Polyzoön*; employed in place of the terms polyzoary or polypidom.

CŒNOSARC (Gr. *koinos*, common; *sarx*, flesh). The common organised medium by which the separate polypites of a compound *Hydrozoön* are connected together.

Coleoptera (Gr. *koleos*, a sheath; *pteron*, wing). The order of Insects (Beetles) in which the anterior pair of wings are hardened, and serve as protective cases for the posterior pair of membranous wings.

Column. Applied to the cylindrical body of a Sea-anemone (*Actinia*); also to the jointed stem or peduncle of the stalked *Crinoids*.

Columella (Lat. diminutive of *columna*, a column). In Conchology, the central axis round which the whorls of a spiral univalve are wound. Amongst the *Actinozoa*, it is the central axis or pillar which is found in the centre of the thecæ of many corals.

Commissural (Lat. *committo*, I solder together). Connecting together; usually applied to the nerve-fibres which unite different ganglia.

Conchifera (Lat. *concha*, a shell; *fero*, I carry). Shell-fish. Applied in a restricted sense to the bivalve Molluscs, and used as a synonym for *Lamellibranchiata*.

Copepoda (Gr. *kope*, an oar; *poda*, feet). An order of *Crustacea*.

Coralligenous. Producing a corallum.

Corallite. The corallum secreted by an *Actinozoön* which consists of a single polype; or the portion of a composite corallum which belongs to, and is secreted by, an individual polype.

Corallum (from the Latin for Red Coral). The hard structures deposited in, or by, the tissues of an *Actinozoön*—commonly called a 'coral.'

Coriaceous (Lat. *corium*, hide). Leathery.

Cortical Layer. The layer of consistent sarcode, which in the *Infusoria* encloses the chyme-mass, and is surrounded by the cuticle. Sometimes called the 'parenchyma of the body.'

Costæ (Lat. *costa*, a rib). Applied amongst the *Crinoidea* to designate the rows of plates which succeed the inferior or basal portion of the cup (pelvis). Amongst the *Corals* the 'costæ' are vertical ridges which occur on the outer surface of the thecæ, and mark the position of the septa within.

Craspeda (Gr. *kraspedon*, a margin or fringe). The long, convoluted cords, containing thread-cells, which are attached to the free margins of the mesenteries of a Sea-anemone.

Crepuscular (Lat. *crepusculum*, dusk). Applied to animals which are active in the dusk or twilight.

Crinoidea (Gr. *krinos*, a lily; *eidos*, form). An order of *Echinodermata*, comprising forms which are usually stalked, and sometimes resemble lilies in shape.

Crop. A partial dilatation of the gullet, technically called 'ingluvies.'

Crustacea (Lat. *crusta*, a crust). A class of articulate animals, comprising Crabs, Lobsters, &c., characterised by the possession of a hard shell or crust, which they cast periodically.

Ctenocyst (Gr. *kteis*, a comb; *kustis*, a bag, or cyst). The sense-organ (probably auditory) which occurs in the *Ctenophora*.

Ctenophora (Gr. *kteis*, a comb; and *phero*, I carry). An order of *Actinozoa*, comprising oceanic creatures, which swim by means of 'ctenophores,' or bands of cilia arranged in comb-like plates.

Cuticle (Lat. *cuticula*, dim. of *cutis*, skin). The pellicle which forms the outer layer of the body amongst the *Infusoria*.

Cyst (Gr. *kustis*, a bladder or bag). A sac, or vesicle.

Cystica. The embryonic forms (scolices) of certain intestinal worms (tapeworms), which were described as a distinct order, until their true nature was discovered.

Cystoidea (Gr. *kustis*, a bladder; and *eidos*, form). An extinct order of *Echinodermata*.

Decapoda (Gr. *deka*, ten, *poda*, feet). The division of *Crustacea*, which have ten ambulatory feet; also the family of Cuttle-fishes, in which there are ten arms or cephalic processes.
Deciduous (Lat. *decido*, I fall off). Applied to parts which fall off or are shed during the life of the animal.
Decollated (Lat. *decollo*, I behead). Applied to univalve shells, the apex of which falls off in the course of growth.
Dendriform, Dendritic, Dendroid (Gr. *dendron*, a tree). Branched like a tree, arborescent.
Dermal (Gr. *derma*, skin). Belonging to the integument.
Dermosclerites (Gr. *derma*, skin, *skleros*, hard). Masses of spicules which occur in the tissues of some of the *Alcyonidæ* (*Actinozoa*).
Desmidiæ. Minute fresh-water plants, of a green colour, without a siliceous epidermis.
Deuterozoöids (Gr. *deuteros*, second; *zoön*, animal; *eidos*, form). The zoöids which are produced by gemmation from zoöids.
Dextral (Lat. *dextra*, the right hand). Right-handed; applied to the direction of the spiral in the greater number of univalve shells.
Diastole (Gr. *diastello*, I separate or expand). The expansion of a contractile cavity such as the heart, which follows its contraction or 'systole.'
Diatomaceæ (Gr. *diatemno*, I sever). An order of minute plants, which are provided with siliceous envelopes.
Dibranchiata (Gr. *dis*, twice; *bragchia*, gill). The order of *Cephalopoda* (comprising the Cuttle-fishes, &c.) in which only two gills are present.
Dimyary (Gr. *dis*, twice; *muon*, muscle). Applied to those bivalve Molluscs (*Lamellibranchiata*) in which the shell is closed by two adductor muscles.
Diœcious (Gr. *dis*, twice; *oikos*, house). Having the sexes distinct; applied to species which consist of male and female individuals.
Dimerosomata (Gr. *dis*; *meros*, part; *soma*, body). An order of *Arachnida*, comprising the true Spiders, so called from the marked division of the body into two regions, the cephalothorax and abdomen. The name *Araneida* is often employed for the order.
Diphyozoöids. Detached reproductive portions of adult *Calycophoridæ*, an order of oceanic *Hydrozoa*.
Diptera (Gr. *dis*, twice; *pteron*, wing). An order of Insects, characterised by the possession of two wings.
Discoid (Gr. *diskos*, a quoit; *eidos*, form). Shaped like a round plate or quoit.
Discophora (Gr. *diskos*, a quoit; *phero*, I carry). This term is applied to the *Medusæ*, or Jelly-fishes from their form; and is sometimes used to designate the order of the Leeches (*Hirudinea*), from the suctorial discs which these animals possess.
Dissepiments (Lat. *dissepio*, I partition off). Partitions. Used in a restricted sense to designate certain imperfect transverse partitions, which grow from the septa of many corals.
Distal. Applied to the quickly growing end of the hydrosoma of a *Hydrozoön*; the opposite, or 'proximal,' extremity growing less rapidly, and being the end by which the organism is fixed, when attached at all.
Diverticulum (Lat. *diverticulum*, a bye-road). A lateral tube with a blind extremity, springing from the side of another tube.
Dorsibranchiate (Lat. *dorsum*, the back; Gr. *bragchia*, gill). Having external gills attached to the back; applied to certain *Annelides* and

Molluscs. The term is of mongrel composition, and 'notobranchiate' is more correctly employed.

ECDERON (Gr. *ek*, out; *deros*, skin). The outer plane of growth of the external integumentary layer (viz. the ectoderm or epidermis).
ECDYSIS (Gr. *ekdusis*, a stripping off). A shedding or moulting of the skin.
ECHINOCOCCI (Gr. *echinos*, a hedge-hog; *kokkos*, a berry). The larval forms (Scolices) of the tapeworm of the dog (*Tænia echinococcus*), commonly known as 'hydatids.'
ECHINODERMATA (Gr. *echinos*; and *derma*, skin). A class of animals comprising the Sea-urchins, Star-fishes and others, most of which have spiny skins.
ECHINOIDEA (Gr. *echinos*; and *eidos*, form). An order of *Echinodermata*, comprising the Sea-urchins.
ECHINULATE. Possessing spines.
ECTOCYST (Gr. *ektos*, outside; *kustis*, a bladder). The external investment of the cœnœcium of a *Polyzoön*.
ECTODERM (Gr. *ektos*, and *derma*, skin). The external integumentary layer of the *Cœlenterata*.
ECTOSARC (Gr. *ektos*; and *sarx*, flesh). The outer transparent sarcode-layer of certain *Rhizopods*, such as the *Amœba*.
EDENTULOUS. Toothless, without any dental apparatus. Applied to the mouth of any animal, or to the hinge of the bivalve Molluscs.
EDRIOPHTHALMATA (Gr. *hedraios*, sitting; *ophthalmos*, eye). The division of *Crustacea* in which the eyes are sessile, and are not supported upon stalks.
ELYTRA (Gr. *elutron*, a sheath). The chitinous anterior pair of wings in Beetles, which form cases for the posterior membranous wings. Also applied to the scales or plates on the back of the Sea-mouse (*Aphrodite*).
ENCEPHALOUS (Gr. *en*, in; *kephale*, the head). Possessing a distinct head. Usually applied to all the *Mollusca* proper, except the *Lamellibranchiata*.
ENCYSTATION (Gr. *en*, in; *kustis*, a bag). The transformation undergone by certain of the *Protozoa*, when they become motionless, and surround themselves by a thick coating or cyst.
ENDERON (Gr. *en*, in; *deros*, skin). The inner plane of growth of the outer integumentary layer (viz. the ectoderm, or epidermis).
ENDOCYST (Gr. *endon*, within; *kustis*, a bag). The inner membrane or integumentary layer of a *Polyzoön*. In *Cristatella*, where there is no 'ectocyst,' the endocyst constitutes the entire integument.
ENDODERM (Gr. *endon*; and *derma*, skin). The inner integumentary layer of the *Cœlenterata*.
ENDOPODITE (Gr. *endon*; and *pous*, foot). The inner of the two secondary joints into which the typical limb of a *Crustacean* is divided.
ENDOSARC (Gr. *endon*; and *sarx*, flesh). The inner molecular layer of sarcode in the *Amœba*, and other allied *Rhizopods*.
ENDOSKELETON (Gr. *endon*, and *skeletos*, dry). The internal hard structures, such as bones, which serve for the attachment of muscles or the protection of organs, and which are not a mere hardening of the integument.
ENSIFORM (Lat. *ensis*, a sword; *forma*, shape). Sword-shaped.
ENTOMOSTRACA (Gr. *entoma*, insects; *ostrakon*, a shell). Literally Shelled Insects; applied to a division of *Crustacea*.
ENTOZOA (Gr. *entos*, within; *zoön*, animal). Animals which are parasitic in the interior of other animals.
EOCENE (Gr. *eos*, dawn; *kainos*, new or recent). The lowest division of the Tertiary Rocks, in which species of existing shells are to a small extent represented.

Epimera (Gr. *epi*, upon; *mēron*, thigh). The lateral pieces of the dorsal arc of the somite of a *Crustacean*.

Epipodia (Gr. *epi*, upon; *pous*, the foot). Muscular lobes developed from the lateral and upper surfaces of the 'foot' of some *Molluscs*.

Epipodite (Gr. *epi*, upon; *pous*, foot). A process developed upon the basal joint, or 'protopodite,' of some of the limbs of certain *Crustacea*.

Episterna (Gr. *epi*, upon; *sternon*, the breast-bone). The lateral pieces of the inferior, or ventral, arc of the somite of a *Crustacean*.

Epistome (Gr. *epi*; and *stoma*, mouth). A valve-like organ which arches over the mouth in certain of the *Polyzoa*.

Epitheca (Gr. *epi*; and *thcke*, a sheath). A continuous layer surrounding the thecæ in some Corals, and being the external indications of tabulæ.

Epizoa (Gr. *epi*, upon; *zoön*, animal). Animals which are parasitic upon other animals. In a restricted sense, a division of *Crustacea* which are parasitic upon fishes.

Equilateral (Lat. *æquus*, equal; *latus*, side). Having its sides equal. Usually applied to the shells of the *Brachiopoda*. When applied to the spiral shells of the *Foraminifera*, it means that all the convolutions of the shell lie in the same plane.

Errantia (Lat. *erro*, I wander). An order of *Annelida*, often called *Nereidea*, distinguished by their great locomotive powers.

Eurypterida (Gr. *eurus*, broad; *pteron*, wing). An extinct sub-order of *Crustacea*.

Exopodite (Gr. *exo*, outside; *pous*, foot). The outer of the two secondary joints into which the typical limb of a *Crustacean* is divided.

Exoskeleton (Gr. *exo*, outside; *skeletos*, dry). The external skeleton, which is constituted by a hardening of the outer layer of the integument, and is often called a 'dermoskeleton.'

Fasciculated (Lat. *fasciculus*, a bundle). Arranged in bundles.

Fauna (Lat. *Fauni*, the rural deities of the Romans). The general assemblage of the animals of any region or district.

Filiform (Lat. *filum*, a thread; *forma*, shape). Thread-shaped.

Fission (Lat. *findo*, I cleave). Multiplication by means of a process of self-division.

Fissiparous (Lat. *findo*; and *pario*, I produce). Giving origin to fresh structures by a process of fission.

Flagellum (Lat. for whip). The lash-like appendage exhibited by many *Infusoria*, which are, therefore, said to be 'flagellate.'

Flora (Lat. *Flora*, the goddess of flowers). The general assemblage of the plants of any region or district.

Foot-jaws. The limbs of *Crustacea*, which are modified to subserve mastication.

Foot-secretion. The term applied by Mr. Dana to the sclerobasic corallum of certain *Actinozoa*.

Foot-tubercles. The unarticulated appendages of the *Annelida*, often called parapodia.

Foraminifera (Lat. *foramen*, an aperture; *fero*, I carry). An order of *Protozoa*, usually characterised by the possession of a shell perforated by numerous pseudopodial apertures.

Fusiform (Lat. *fusus*, a spindle; and *forma*, shape). Spindle-shaped, or pointed at both ends.

Ganglion (Gr. *gagglion*, a knot). A mass of nervous matter, giving origin to nerve-fibres.

GASTEROPODA (Gr. *gaster*, stomach; *pous*, foot). The class of the *Mollusca*, comprising the ordinary univalves, in which locomotion is usually effected by a muscular expansion of the under surface of the body (the 'foot').

GEMMÆ (Lat. *gemma*, a bud). The buds produced by any animal, whether detached or not.

GEMMATION. The process of producing new structures by budding.

GEMMIPAROUS (Lat. *gemma*, a bud; *pario*, I produce). Giving origin to new structures by a process of budding.

GEMMULES (Lat. dim. of *gemma*). The ciliated embryos of many *Cœlenterata*; also the seed-like reproductive bodies, or 'spores,' of *Spongilla*.

GLADIUS (Lat. a sword). Applied to the horny endoskeleton, or 'pen,' of certain Cuttle-fishes.

GNATHITES (Gr. *gnathos*, a jaw). The masticatory organs of *Crustacea*.

GONOBLASTIDIA (Gr. *gonos*, offspring; *blastidion*, dim. of *blastos*, a bud). The processes which carry the reproductive receptacles, or 'gonophores,' in many of the *Hydrozoa*.

GONOCALYX (Gr. *gonos*; and *kalux*, cup). The swimming-bell in a medusiform gonophore, or the same structure in a gonophore which is not detached.

GONOPHORE (Gr. *gonos*; and *phero*, I carry). The generative buds, or receptacles of the reproductive elements, in the *Hydrozoa*, whether these become detached or not.

GONOSOME (Gr. *gonos*; and *soma*, body). Applied as a collective term to the reproductive zoöids of a *Hydrozoön*.

GONOTHECA (Gr. *gonos*; and *theke*, a case). The chitinous receptacle, within which the gonophores of certain of the *Hydrozoa* are produced.

GRAPTOLITIDÆ (Gr. *grapho*, I write; *lithos*, stone). An extinct sub-class of the *Hydrozoa*.

GUARD. The cylindrical fibrous sheath with which the internal chambered shell (phragmacone) of a *Belemnite* is protected.

GYMNOLÆMATA (Gr. *gumnos*, naked; *laima*, the throat). An order of the *Polyzoa*, in which the mouth is devoid of the valvular structure known as the 'epistome.'

GYMNOPHTHALMATA (Gr. *gumnos*; and *ophthalmos*, the eye). Applied by Edward Forbes to those *Medusæ* in which the eye-specks at the margin of the disc are unprotected. The division is now abandoned.

GYMNOSOMATA (Gr. *gumnos*, and *soma*, the body). The order of *Pteropoda*, in which the body is not protected by a shell.

GYNOPHORES (Gr. *gune*, woman; *phero*, I carry. The generative buds, or gonophores, of *Hydrozoa*, which contain ova alone, and differ in form from those which contain spermatozoa.

HÆMAL (Gr. *haima*, blood). Connected with the bloodvessels, or with the circulatory system.

HALTERES (Gr. *halteres*, weights used by athletes to steady themselves in leaping). The rudimentary filaments, or 'balancers,' which represent the posterior pair of wings in the *Diptera*, an order of Insects.

HAUSTELLATE (Lat. *haurio*, I drink). Adapted for sucking or pumping up fluids; applied to the mouth of certain *Crustacea* and *Insecta*.

HECTOCOTYLUS (Gr. *hekaton*, a hundred; *kotulos*, a cup). The metamorphosed reproductive arm of certain of the male Cuttle-fishes. In the *Argonaut* the arm becomes detached, and was originally described as a parasitic worm.

HELMINTHOID (Gr. *helmins*, an intestinal worm). Worm-shaped, vermiform.

HEMELYTRA (Gr. *hemi*, half; *elutron*, a sheath). The wings of certain insects, in which the apex of the wing is membranous, whilst the inner portion is chitinous, and resembles the elytron of a beetle.

HEMIMETABOLIC (Gr. *hemi*, half; *metabole*, change). Applied to those Insects which undergo an incomplete metamorphosis.

HEMIPTERA (Gr. *hemi*; and *pteron*, wing). An order of Insects in which the anterior wings are 'hemelytra.'

HERMAPHRODITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Possessing the characters of both sexes combined.

HETEROGANGLIATE (Gr. *heteros*, diverse; *gagglion*, a knot). Possessing a nervous system in which the ganglia are scattered and unsymmetrical (as in the *Mollusca* for example).

HEXAPOD (Gr. *hexa*, six; *pous*, foot). Possessing six legs; applied to the *Insecta*.

HILUM (Lat. *hilum*, a little thing). A small aperture (as in the gemmules of sponges), or a small depression (as in *Noctiluca*).

HIRUDINEA (Lat. *hirudo*, a horse-leech). The order of *Annelida*, comprising the Leeches.

HISTOLOGY (Gr. *histos*, a web; *logos*, a discourse). The study of the tissues; more especially of the minuter elements of the body.

HOLOMETABOLIC (Gr. *holos*, whole; *metabole*, change). Applied to Insects which undergo a complete metamorphosis.

HOLOSTOMATA (Gr. *holos*, whole; *stoma*, mouth). A division of *Gasteropodous Molluscs*, in which the aperture of the shell is rounded, or 'entire.'

HOLOTHUROIDEA (Gr. *holos*; *thura*, gate; and *eidos*, form). An order of *Echinodermata*, comprising the Trepangs.

HOMOGANGLIATE (Gr. *homos*, like; *gagglion*, a knot). Having a nervous system in which the ganglia are symmetrically arranged (as in the *Annulosa*, for example).

HOMOLOGOUS (Gr. *homos*; and *logos*, a discourse). Applied to parts which are constructed upon the same fundamental plan.

HOMOMORPHOUS (Gr. *homos*; and *morphe*, form). Having a similar external appearance or form.

HYALINE (Gr. *hualos*, crystal). Crystalline or glassy.

HYDATIDS (Gr. *hudatis*, a vesicle). The vesicle containing the larval forms (*Echinococci*) of the tape-worm of the dog.

HYDRAFORM. Resembling the common fresh-water polype (*Hydra*) in form.

HYDROCAULUS (Gr. *hudra*, a water-serpent, and *kaulos*, a stem). The main stem of the cœnosarc of a *Hydrozoön*.

HYDROCYSTS (Gr. *hudra*; and *kustis*, a cyst). Curious processes attached to the cœnosarc of the *Physophoridæ*, and termed 'feelers' (*fühler* and *taster* of the Germans).

HYDRŒCIUM (Gr. *hudra*; and *oikos*, a house). The chamber into which the cœnosarc in many of the *Calycophoridæ* can be retracted.

HYDROIDA (Gr. *hudra*; and *eidos*, form). The sub-class of the *Hydrozoa*, which comprises the animals most nearly allied to the *Hydra*.

HYDROPHYLLIA (Gr. *hudra*; and *phyllon*, a leaf). Overlapping appendages or plates, which protect the polypites in some of the Oceanic *Hydrozoa* (*Calycophoridæ* and *Physophoridæ*). They are often termed 'bracts,' and are the '*deckstücke*' of the Germans.

HYDRORHIZA (Gr. *hudra*; and *rhiza*, root). The adherent base or proximal extremity of any *Hydrozoön*.

HYDROSOMA (Gr. *hudra*; and *soma*, body). The entire organism of any *Hydrozoön*.

HYDROTHECA (Gr. *hudra*; and *theke*, a case). The little chitinous cups in which the polypites of the *Sertularida* and *Campanularida* are protected.

HYDROZOA (Gr. *hudra*; and *zoön*, animal). The class of the *Cœlenterata*, which comprises animals constructed after the type of the *Hydra*.

HYMENOPTERA (Gr. *humen*, a membrane; *pteron*, a wing). An order of Insects (comprising Bees, Ants, &c.) characterised by the possession of four membranous wings.

HYPOSTOME (Gr. *hupo*, under; *stoma*, mouth). The upper lip, or 'labrum' of certain *Crustacea* (e.g. Trilobites).

ICHTHYOPHTHIRA (Gr. *ichthus*, fish; *phtheir*, a louse). An order of *Crustacea*, comprising animals which are parasitic upon fishes.

IMAGO (Lat. an image, or apparition). The perfect insect, after it has undergone its metamorphosis.

IMBRICATED. Applied to scales or plates which overlap one another like tiles.

INEQUILATERAL. Having the two sides unequal; as in the case of the shells of the ordinary bivalves (*Lamellibranchiata*). When applied to the shells of the *Foraminifera*, it implies that the convolutions of the shell do not lie in the same plane, but are obliquely wound round an axis.

INFUNDIBULUM (Lat. for funnel). The tube formed by the coalescence or apposition of the epipodia in the *Cephalopoda*. Commonly termed the 'funnel,' or 'siphon.'

INFUSORIA (Lat. *infusum*, an infusion). A class of *Protozoa*, so called because they are often developed in organic infusions.

INOPERCULATA (Lat. *in*, without; *operculum*, a lid). The division of pulmonate *Gasteropoda* in which there is no shelly or horny plate (operculum) by which the shell is closed when the animal is withdrawn within it.

INSECTA (Lat. *inseco*, I cut into). The class of Articulate animals commonly known as Insects.

INTERAMBULACRA. The rows of plates in an *Echinoderm*, which are not perforated for the emission of the 'tube-feet.'

INTUSSUSCEPTION (Lat. *intus*, within; *suscipio*, I take up). The act of taking foreign matter into a living being.

INVERTEBRATA (Lat. *in*, without; *vertebra*, a bone of the back). Animals without a spinal column or backbone.

ISOPODA (Gr. *isos*, equal; *poda*, feet). An order of *Crustacea* in which the feet are like one another and equal.

KAINOZOIC (Gr. *kainos*, recent; *zoe*, life). The Tertiary period in Geology, comprising those formations in which the organic remains approximate more or less closely to the existing fauna and flora.

KERATODE (Gr. *keras*, horn; *eidos*, form). The horny substance of which the skeleton of many sponges is made up.

KERATOSA. The division of Sponges in which the skeleton is composed of keratode.

LABIUM (Lat. for lip). Restricted to the lower lip of Articulate animals.

LABRUM (Lat. for lip). Restricted to the upper lip of Articulate animals.

LÆMODIPODA (Gr. *laima*, throat; *dis*, twice; *poda*, feet). An order of *Crustacea*, so called because they have two feet placed far forwards, as it were under the throat.

LAMELLIBRANCHIATA (Lat. *lamella*, a plate, Gr. *bragchia*, gill). The class of *Mollusca*, comprising the ordinary bivalves, characterised by the possession of lamellar gills.

Larva (Lat. a mask). The insect in its first stage after its emergence from the egg, when it is usually very different from the adult.

Lenticular (Lat. *lens*, a bean). Shaped like a biconvex lens.

Lepidoptera (Gr. *lepis*, a scale; *pteron*, a wing). An order of Insects, comprising Butterflies and Moths, characterised by possessing four wings which are usually covered with minute scales.

Ligula (Lat. *ligula*, a little tongue). The upper flexible portion of the labium or lower lip in Insects.

Lingual (Lat. *lingua*, the tongue). Connected with the tongue.

Lithocysts (Gr. *lithos*, a stone; *kustis*, a cyst). The sense-organs or 'marginal bodies' of the *Lucernarida* or *Steganophthalmate Medusæ*.

Lophophore (Gr. *lophos*, a crest; and *phero*, I carry). The disc or stage upon which the tentacles of the *Polyzoa* are borne.

Lophyropoda (Gr. *lophouros*, having stiff hairs; and *poda*, feet). An order of *Crustacea*.

Lorica (Lat. a breast-plate). Applied to the protective case with which certain *Infusoria* are provided.

Lucernarida (Lat. *lucerna*, a lamp). An order of the *Hydrozoa*.

Macrura (Gr. *makros*, long; *oura*, tail). The tribe of Decapod *Crustaceans* with long tails (e.g. the lobster, shrimp, &c.).

Madreporiform. Perforated with small holes, like a coral; applied to the tubercle by which the ambulacral system of the *Echinoderms* mostly communicates with the exterior.

Malacostraca (Gr. *malakos*, soft; *ostrakon*, shell). A division of *Crustacea*. Originally applied by Aristotle to the entire class *Crustacea*, because their shells were softer than those of the *Mollusca*.

Mallophaga (Gr. *mallos*, a fleece; *phago*, I eat). An order of Insects, which are mostly parasitic upon birds.

Mammalia (Lat. *mamma*, the breast). The class of Vertebrate animals which suckle their young.

Mandibles (Lat. *mandibulum*, a jaw). The upper pair of jaws in Insects; also applied to one of the pairs of jaws in *Crustacea* and Spiders, to the beak of Cephalopods, &c.

Mantle. The external integument of most of the Mollusca, which is largely developed and forms a cloak in which the viscera are protected. Technically called the 'pallium.'

Manubrium (Lat. a handle). The polypite which is suspended from the roof of the swimming-bell of a *Medusa*, or from the gonocalyx of a medusiform gonophore, amongst the *Hydrozoa*.

Mastax (Gr. mouth). The muscular pharynx or 'buccal funnel' into which the mouth opens in most of the *Rotifera*.

Maxillæ (Lat. jaws). The inferior pair or pairs of jaws in the *Arthropoda* (Insects, Crustacea, &c.).

Maxillipedes (Lat. *maxillæ*, jaws; *pes*, the foot). The limbs in *Crustacea* and *Myriapoda*, which are converted into masticatory organs, and are commonly called 'foot-jaws.'

Medusæ. An order of *Hydrozoa*, commonly known as Jelly-fishes (*Discophora*, or *Acalephæ*), so called because of the resemblance of their tentacles to the snaky hair of the Medusa. Many *Medusæ* are now known to be merely the gonophores of *Hydrozoa*.

Medusiform. Resembling a *Medusa* in shape.

Medusoid. Like a *Medusa*; used substantively to designate the medusiform gonophores of the *Hydrozoa*.

Mentum (Lat. the chin). The basal portion of the labium or lower lip in Insects.

Merostomata (Gr. *mēron*, thigh; *stoma*, mouth). An order of *Crustacea*, in which the appendages which are placed round the mouth and which officiate as jaws, have their free extremities developed into walking or prehensile organs.

Mesenteries (Gr. *mesos*, intermediate; *enteron*, intestine). In a restricted sense, the vertical plates which divide the somatic cavity of a Sea-anemone (*Actinia*) into chambers.

Mesopodium (Gr. *mesos*, middle; *pous*, foot). The middle portion of the 'foot' of Molluscs.

Mesothorax (Gr. *mesos*; and *thorax*, the chest). The middle ring of the thorax in Insects.

Mesozoic (Gr. *mesos*; and *zoe*, life). The Secondary period in Geology.

Metapodium (Gr. *meta*, after; *pous*, the foot). The posterior lobe of the foot in *Mollusca*; often called the 'operculigerous lobe,' because it developes the operculum, when this structure is present.

Metastoma (Gr. *meta*, after; *stoma*, mouth). The plate which closes the mouth posteriorly in the *Crustacea*.

Metathorax (Gr. *meta*, after; *thorax*, the chest). The posterior ring of the thorax in insects.

Mimetic (Gr. *mimetikos*, imitative). Applied to organs or animals which resemble each other in external appearance but not in essential structure.

Mollusca (Lat. *mollis*, soft). The sub-kingdom which includes the Shell-fish proper, the *Polyzoa*, the *Tunicata*, and the Lamp-shells; so called from the generally soft nature of their bodies.

Monads (Gr. *monas*, solitary). Microscopical organisms of an extremely simple character, developed in organic infusions.

Monoculous. Possessed of only one eye.

Monœcious (Gr. *monos*, single; *oikos*, house). Applied to individuals in which the sexes are united.

Monomyary (Gr. *monos*, single; *muon*, muscle). Applied to those bivalves (*Lamellibranchiata*) in which the shell is closed by a single adductor muscle.

Monothalamous (Gr. *monos*; and *thalamos*, chamber). Possessing only a single chamber; applied to the shells of *Foraminifera* and *Mollusca*.

Multilocular (Lat. *multus*, many; *loculus*, a little purse). Divided into many chambers.

Multivalve. Applied to shells which are composed of many pieces.

Myriapoda (Gr. *murios*, ten thousand; *poda*, feet). A class of *Arthropoda*, comprising the Centipedes and their allies, characterised by their numerous feet.

Nacreous (Fr. *nacre*, mother-of-pearl, originally Oriental). Pearly, of the texture of mother-of-pearl.

Natatory (Lat. *nare*, to swim). Formed for swimming.

Nautiloid. Resembling the shell of the *Nautilus* in shape.

Nectocalyx (Gr. *necho*, I swim; *kalux*, cup). The swimming-bell, or 'disc' of a *Medusa* or Jelly-fish.

Nematelmia (Gr. *nema*, thread; *helmins*, a worm). The division of *Scolecida*, comprising the Round-worms, Thread-worms, &c.

Nematocysts (Gr. *nema*, thread; *kustis*, a bag). The thread-cells of the *Cœlenterata*. (*See* Cnidæ.)

Nematoidea (Gr. *nema*, thread; *eidos*, form). An order of *Scolecida* comprising the Thread-worms, Vinegar-eels, &c.

Nematophores (Gr. *nema*, thread; *phero*, I carry). Cæcal processes, found on the cœnosarc of certain of the *Sertularida*, containing numerous thread-cells at their extremities.

NEMERTIDA (Gr. *Nemertes*, proper name). A division of the *Turbellarian Worms*, commonly called 'Ribbon-worms.'

NERVURES (Lat. *nervus*, a sinew). The ribs which support the membranous wings of insects.

NEURAL (Gr. *neuron*, a nerve). Connected with the nervous system.

NEUROPODIUM (Gr. *neuron*, a nerve; *pous*, the foot). The ventral or inferior division of the 'foot-tubercle' of an *Annelide*; often called the 'ventral oar.'

NEUROPTERA (Gr. *neuron*; and *pteron*, a wing). An order of Insects, characterised by four membranous wings with numerous reticulated nervures (e.g. Dragon-flies).

NEUTER (Lat. neither the one nor the other). Having no fully developed sex.

NOTOBRANCHIATA (Gr. *notos*, the back; and *bragchia*, gill). Carrying the gills upon the back; applied to a division of the *Annelida*.

NOTOPODIUM (Gr. *notos*, the back, and *pous*, the foot). The dorsal division of one of the foot-tubercles or parapodia of an *Annelide*; often called the 'dorsal oar.'

NUCLEATED. Possessing a nucleus or central particle.

NUCLEOLUS. 1. The minute solid particle in the interior of the nucleus of some cells. 2. The minute spherical particle attached to the exterior of the 'nucleus,' or ovary, of certain *Infusoria*, performing the functions of a testicle.

NUCLEUS (Lat. *nucleus*, a kernel). 1. The solid or vesicular body found in many cells. 2. The solid rod- or band-shaped body, found in the interior of many of the *Protozoa*, and having, in certain of them, the functions of an ovary. 3. The 'madreporiform tubercle' of the *Echinodermata*. 4. The embryonic shell which is retained to form the apex of the adult shell, in many of the *Mollusca*.

NUDIBRANCHIATA (Lat. *nudus*, naked; and Gr. *bragchia*, gill). An order of the *Gasteropoda* in which the gills are naked.

NYMPHS. The active pupæ of certain Insects.

OCEANIC, applied to animals which inhabit the open ocean (= pelagic).

OCELLI (Lat. diminutive of *oculus*, eye). The simple eyes of many Echinoderms, Spiders, Crustaceans, Molluscs, &c.

OCTOPODA (Gr. *octo*, eight; *pous*, foot). The tribe of Cuttle-fishes, with eight arms attached to the head.

ODONTOPHORE (Gr. *odous*, tooth; *phero*, I carry). The so-called 'tongue,' or masticatory apparatus of *Gasteropoda*, *Pteropoda*, and *Cephalopoda*.

ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.

OLIGOCHÆTA (Gr. *oligos*, few; *chaite*, hair). An order of *Annelida*, comprising the Earth-worms, in which there are few bristles.

OPERCULATA (Lat. *operculum*, a lid). A division of pulmonate *Gasteropoda*, in which the shell is closed by an operculum.

OPERCULUM. A horny or shelly plate developed in certain *Mollusca* upon the hinder part of the foot, and serving to close the aperture of the shell when the animal is retracted within it; also the lid of the shell of a *Balanus* or Acorn-shell.

OPHIUROIDEA (Gr. *ophis*, snake; *oura*, tail; *eidos*, form). An order of *Echinodermata*, comprising the Brittle-stars and Sand-stars.

OPISTHOBRANCHIATA (Gr. *opisthon*, behind; *bragchia*, gill). A division of *Gasteropoda*, in which the gills are placed on the posterior part of the body.

ORAL (Lat. *os*, mouth). Connected with the mouth.

ORTHOPTERA (Gr. *orthos*, straight; *pteron*, wing). An order of Insects.

OSCULA (Lat. diminutive of *os*, mouth). 1. The large apertures by which a sponge is perforated ('exhalent apertures'). 2. The suckers with which the *Tæniada* (Tape-worms and Cystic Worms) are provided.

OSSICULA (Lat. diminutive of *os*, bone). Literally small bones. Often used to designate any hard structures of small size, such as the calcareous plates in the integument of the Star-fishes.

OSTRACODA (Gr. *ostrakon*, a shell). An order of small Crustaceans, which are enclosed in bivalve shells.

OTOLITHS (Gr. *ous*, ear; and *lithos*, stone). The calcareous bodies connected with the sense of hearing, even in its most rudimentary form.

OVARIAN VESICLES or CAPSULES. The gonophores or generative buds of the *Hydrozoa*.

OVARY (OVARIUM). The organ by which ova are produced.

OVIPAROUS (Lat. *ovum*, an egg; and *pario*, I bring forth). Applied to animals which bring forth eggs, in contradistinction to those which bring forth their young alive.

OVIPOSITOR (Lat. *ovum*, and *pono*, I place). The organ possessed by some insects, by means of which the eggs are placed in a position suitable for their development.

OVOVIVIPAROUS (Lat. *ovum*, egg; *vivus*, alive; *pario*, I produce). Applied to animals which retain their eggs within the body until they are hatched.

OVUM (Lat. an egg). The germ produced within the ovary, and capable under certain conditions of being developed into a new individual.

PALÆONTOLOGY (Gr. *palaios*, ancient; and *logos*, discourse. The science of fossil remains or of extinct organised beings.

PALÆOZOIC (Gr. *palaios*, ancient; and *zoe*, life). Applied to the oldest of the great geological epochs.

PALLIUM (Lat. *pallium*, a cloak). The mantle of the *Mollusca*. *Pallial*: relating to the mantle. *Pallial line* or *impression*: the line left in the dead shell by the muscular margin of the mantle. *Pallial shell*: a shell which is secreted by, or contained within, the mantle, such as the 'bone' of the Cuttle-fishes.

PALLIOBRANCHIATA (Lat. *pallium*; and Gr. *bragchia*, gill). An old name for the *Brachiopoda*, founded upon the belief that the system of tubes in the mantle constituted the gills.

PALPI (Lat. *palpo*, I touch). Processes, supposed to be organs of touch, developed from certain of the oral appendages in Insects, Spiders, and Crustacea; and from the sides of the mouth in the Acephalous Molluscs.

PAPILLA (Lat. for nipple). A minute soft prominence.

PARIETAL (Lat. *paries*, a wall). Connected with the walls of a cavity or of the body.

PARIETOSPLANCHNIC (Lat. *paries*; Gr. *splagchnon*, viscera). Applied to one of the nervous ganglia of the *Mollusca*, which supplies the walls of the body and the viscera.

PARTHENOGENESIS (Gr. *parthenos*, a virgin; and *gignomai*, to be born). Strictly speaking, confined to the production of new individuals from virgin females by means of ova, without the intervention of a male. Sometimes used also to designate asexual reproduction by gemmation or fission.

PECTINATE (Lat. *pecten*, a comb). Comb-like; applied to the gills of certain *Gasteropods*, hence called *Pectinibranchiata*.

PEDAL (Lat. *pes*, the foot). Connected with the foot of *Mollusca*.

PEDICELLARIÆ (Lat. *pedicellus*, a louse). Certain singular appendages found in many *Echinoderms,* attached to the surface of the body, and resembling a little beak or forceps, supported on a stalk.

PEDICLE (Lat. dim. of *pes,* the foot). A little stem.

PEDIPALPI (Lat. *pes,* foot; and *palpo,* I feel). An order of *Arachnida* comprising the Scorpions, &c.

PEDUNCLE (Lat. *pedunculus,* a stem or stalk). In a restricted sense, applied to the muscular process by which certain *Brachiopods* are attached, and to the stem which bears the body (capitulum) in Barnacles.

PEDUNCULATE. Possessing a peduncle.

PELAGIC (Gr. *pelagos,* sea). Inhabiting the open ocean.

PELVIS (Lat. for basin). Applied, from analogy, to the basal portion of the cup (*calyx*) of *Crinoids.*

PERGAMENTACEOUS (Lat. *pergamena,* parchment). Of the texture of parchment.

PERIDERM (Gr. *peri,* around; and *derma,* skin). The hard cuticular layer which is developed by the cœnosarc of certain of the *Hydrozoa.*

PERIGASTRIC (Gr. *peri,* around; and *gaster,* stomach). The perigastric space is the cavity which surrounds the stomach and other viscera, corresponding to the abdominal cavity of the higher animals.

PERIOSTRACUM (Gr. *peri*; and *ostrakon,* shell). The layer of epidermis which covers the shell in most of the *Mollusca.*

PERIPLAST (Gr. *peri*; and *plasso,* I mould). The intercellular substance or matrix, in which the organised structures of a tissue are imbedded.

PERISOME (Gr. *peri*; and *soma,* body). The coriaceous or calcareous integument of the *Echinodermata.*

PERISTOME (Gr. *peri*; and *stoma,* mouth). The space which intervenes between the mouth and the margin of the calyx in *Vorticella*; also the space between the mouth and the tentacles in a Sea-anemone (*Actinia*); also the lip or margin of the mouth of a univalve shell.

PERIVISCERAL (Gr. *peri*; and Lat. *viscera,* the internal organs). Applied to the space surrounding the viscera.

PETALOID. Shaped like the petal of a flower.

PHARYNX. The dilated commencement of the gullet.

PHRAGMACONE (Gr. *phragma,* a partition; and *konos,* a cone). The chambered portion of the internal shell of a *Belemnite.*

PHYLACTOLÆMATA (Gr. *phulasso,* I guard, and *laima,* throat). The division of *Polyzoa,* in which the mouth is provided with the arched valvular process known as the 'epistome.'

PHYLLOCYSTS (Gr. *phullon,* leaf; and *kustis,* a cyst). The cavities in the interior of the 'hydrophyllia' of certain of the Oceanic *Hydrozoa.*

PHYLLOPODA (Gr. *phullon,* leaf; and *pous,* foot). An order of *Crustacea.*

PHYOGEMMARIA (Gr. *phuo,* I produce; and Lat. *gemma,* bud). The small gonoblastidia of *Velella,* one of the *Physophoridæ.*

PHYSOGRADA (Gr. *phusa,* bellows or air-bladder; and Lat. *gradior,* I walk). Applied formerly to the *Physophoridæ,* an order of Oceanic *Hydrozoa,* in which a 'float' is present.

PHYSOPHORIDÆ (Gr. *phusa,* air-bladder; and *phero,* I carry). An order of Oceanic *Hydrozoa.*

PHYTOID (Gr. *phuton,* a plant; and *eidos,* form). Plant-like.

PHYTOPHAGOUS (Gr. *phuton,* a plant; and *phago,* I eat). Plant-eating, or herbivorous.

PINNATE (Lat. *pinna,* a feather). Feather-shaped, or possessing lateral processes.

PINNULÆ (Lat. dim. of *pinna*). The lateral processes of the arms of *Crinoids.*

PLANARIDA (Gr. *planē*, wandering). A sub-order of the *Turbellaria*.
PLANULA (Lat. *planus*, flat). The oval ciliated embryo of certain of the *Hydrozoa*.
PLATYELMIA (Gr. *platus*, broad; and *helmins*, an intestinal worm). The division of *Scolecida* comprising the Tape-worms, &c.
PLEURON (Gr. *pleuron*, a rib). The lateral extensions of the shell of *Crustacea*.
PNEUMATOCYST (Gr. *pneuma*, air; and *kustis*, cyst). The air-sac or float of certain of the Oceanic *Hydrozoa* (*Physophoridæ*).
PNEUMATOPHORE (Gr. *pneuma*, air; and *phero*, I carry). The proximal dilatation of the cœnosarc in the *Physophoridæ*, which surrounds the pneumatocyst.
PNEUMOSKELETON (Gr. *pneuma*; and *skeletos*, dry). The hard structures which are connected with the breathing organs (e.g. the shell of Molluscs).
PODOPHTHALMATA (Gr. *pous*, foot; and *ophthalmos*, eye). The division of Crustacea in which the eyes are borne at the end of long foot-stalks.
PODOSOMATA (Gr. *pous*, foot, *soma*, body). An order of *Arachnida*.
POLYCYSTINA (Gr. *polus*, many; and *kustis*, a cyst). An order of *Protozoa*, with foraminated siliceous shells.
POLYGASTRICA (Gr. *polus*; and *gaster*, stomach). The name applied by Ehrenberg to the *Infusoria*, under the belief that they possessed many stomachs.
POLYPARY. The hard, chitinous covering secreted by many of the *Hydrozoa*.
POLYPE (Gr. *polus*, many; *pous*, foot). Restricted to the single individual of a simple *Actinozoön*, such as a Sea-anemone, or to the separate zoöids of a compound *Actinozoön*. Often applied indiscriminately to any of the *Cœlenterata*, or even to the *Polyzoa*.
POLYPIDE. The separate zoöid of a *Polyzoön*.
POLYPIDOM. The dermal system of a colony of a *Hydrozoön*, or *Polyzoön*.
POLYPITE. The separate zoöid of a *Hydrozoön*.
POLYSTOME (Gr. *polus*, many; and *stoma*, mouth). Having many mouths; applied to the *Acinetæ* amongst the *Protozoa*.
POLYTHALAMOUS (Gr. *polus*; and *thalamos*, chamber). Having many chambers; applied to the shells of *Foraminifera* and *Cephalopoda*.
POLYZOA (Gr. *polus*; and *zoön*, animal). A division of the *Molluscoida*, comprising compound animals, such as the Sea-mat. Sometimes called *Bryozoa*.
POLYZOARIUM. The dermal system of the colony of a *Polyzoön* (= Polypidom).
PORCELLANOUS. Of the texture of porcelain.
PORIFERA (Lat. *porus*, a pore; and *fero*, I carry). Sometimes used to designate the *Foraminifera*, or the *Sponges*.
POST-ANAL. Situated behind the anus.
POST-ŒSOPHAGEAL. Situated behind the gullet.
POST-ORAL. Situated behind the mouth.
PRÆ-ŒSOPHAGEAL. Situated in front of the gullet.
PROBOSCIS (Lat. or Gr. the snout). Applied to the spiral trunk of *Lepidopterous Insects*, to the projecting mouth of certain *Crinoids*, and to the central polypite in the *Medusæ*.
PROGLOTTIS (Gr. for the tip of the tongue). The generative segment or joint of a tape-worm.
PRO-LEGS. The false abdominal feet of caterpillars.
PROPODIUM (Gr. *pro*, before; *pous*, foot). The anterior part of the foot in Molluscs.

PROSCOLEX (Gr. *pro*, before; *skolex*, worm). The first embryonic stage of a Tape-worm.

PROSOBRANCHIATA (Gr. *proson*, in advance of; *bragchia*, a gill). A division of Gasteropodous Molluscs in which the gills are situated in advance of the heart.

PROSOMA (Gr. *pro*, before; *soma*, body). The anterior part of the body.

PROTHORAX (Gr. *pro*; and *thorax*, chest). The anterior ring of the thorax of insects.

PROTOPODITE (Gr. *protos*, first; and *pous*, foot). The basal segment of the typical limb of a *Crustacean*.

PROTOPHYTA (Gr. *protos*; and *phuton*, plant). The lowest division of plants.

PROTOPLASM (Gr. *protos*; and *plasso*, I mould). The elementary basis of organised tissues—consisting of an albuminoid, coagulable body. Sometimes used synonymously for 'sarcode.'

PROTOZOA (Gr. *protos*; and *zoön*, animal). The lowest division of the animal kingdom.

PROXIMAL (Lat. *proximus*, next). The slowly-growing comparatively fixed extremity of a limb or of an organism.

PSEUDEMBRYO (Gr. *pseudos*, false; *embruon*, embryo). The larval form of an *Echinoderm*.

PSEUDO-HÆMAL (Gr. *pseudos*; false, and *haima*, blood). Applied to the vascular system of *Annelida*.

PSEUDO-HEARTS. Certain contractile cavities connected with the atrial system of *Brachiopoda*, and long considered to be hearts.

PSEUDO-NAVICELLÆ (Gr. *pseudos*, false; and *Navicula*, a genus of Diatoms). The embryonic forms of the *Gregarinidæ*, so called from their resemblance in shape to the *Navicula*.

PSEUDOPODIA (Gr. *pseudos*; and *pous*, foot). The extensions of the body-substance which are put forth by the *Rhizopoda* at will, and which serve for locomotion and prehension.

PSEUDOVA (Gr. *pseudos*; Lat. *ovum*, egg). The egg-like bodies from which the young of the viviparous *Aphis* are produced.

PTEROPODA (Gr. *pteron*, wing; and *pous*, foot). A class of the *Mollusca*, which swim by means of fins attached near the head.

PULMONARIA. A division of *Arachnida*, which breathe by means of pulmonary sacs.

PULMONATE. Possessing lungs.

PULMONIFERA (Lat. *pulmo*, a lung; and *fero*, I carry). The division of *Mollusca* which breathe by means of a pulmonary chamber.

PULMOGASTEROPODA (= Pulmonifera).

PUPA (Lat. a doll). The stage of an insect, immediately preceeding its appearance in a perfect condition. In the pupa-stage it is usually quiescent—when it is often called a 'chrysalis'—but it is sometimes active—when it is often called a 'nymph.'

PYRIFORM (Lat. *pyrus*, a pear, and *forma*, form). Pear-shaped.

RADIATA (Lat. *radius*, a ray). Formerly applied to a large number of animals, which are now placed in separate sub-kingdoms (e.g. the *Cœlenterata*, the *Echinodermata*, the *Infusoria*, &c.).

RADIOLARIA (Lat. *radius*, a ray). A division of *Protozoa*.

RETICULARIA (Lat. *reticulum*, a net). Employed by Dr. Carpenter to designate those *Protozoa*, such as the *Foraminifera*, in which the pseudopodia run into one another and form a net-work.

REVERSED. Applied to spiral univalves, in which the direction of the spiral is the reverse of the normal; i.e. *sinistral*.

RHIZOPODA (Gr. *rhiza*, root; and *pous*, foot). The division of *Protozoa* comprising all those which are capable of emitting pseudopodia.

RHYNCHOLITES (Gr. *rhunchos*, beak; and *lithos*, stone). Beak-shaped fossils, consisting of the mandibles of *Cephalopoda*.

ROSTRUM (Lat. *rostrum*, beak). The 'beak,' or suctorial organ formed by the appendages of the mouth in certain insects.

ROTATORIA (= Rotifera).

ROTIFERA (Lat. *rota*, wheel; and *fero*, I carry). A class of the *Scolecida* (*Annuloida*), characterised by a ciliated 'trochal disc.'

RUGOSA (Lat. *rugosus*, wrinkled). An extinct order of Corals.

SAND-CANAL (= STONE-CANAL). The tube by which water is conveyed from the exterior to the ambulacral system of the *Echinodermata*.

SARCODE (Gr. *sarx*, flesh; *eidos*, form). The jelly-like substance of which the bodies of *Protozoa* are composed. It is an albuminous body containing oil-granules, and is sometimes called 'animal protoplasm.'

SARCOIDS (Gr. *sarx*; and *eidos*, form). The separate amœbiform particles which in the aggregate make up the 'flesh' of a Sponge.

SCAPHOGNATHITE (Gr, *skaphos*, boat; and *gnathos*, jaw). The boat-shaped appendage (epipodite) of the second pair of maxillæ in the Lobster; the function of which is to spoon out the water from the branchial chamber.

SCAPULA (Lat. for shoulder-blade). The shoulder-blade; in a restricted sense, the row of plates in the cup of *Crinoids*, which give origin to the arms, and are usually called the 'axillary radials.'

SCLERENCHYMA (Gr. *skleros*, hard; and *enchyma*, tissue). The calcareous tissue of which a coral is composed.

SCLERITES (Gr. *skleros*). The calcareous spicules which are scattered in the soft tissues of certain *Actinozoa*.

SCLEROBASIC (Gr. *skleros*, hard; *basis*, pedestal). The coral which is produced by the outer surface of the integument in certain *Actinozoa* (e.g. Red Coral) and forms a solid axis which is invested by the soft parts of the animal. It is called 'foot-secretion' by Mr. Dana.

SCLERODERMIC (Gr. *skleros*; and *derma*, skin). Applied to the corallum which is deposited within the tissues of certain *Actinozoa*, and is called 'tissue-secretion' by Mr. Dana.

SCOLECIDA (Gr. *skolēx*, worm). A division of the *Annuloida*.

SCOLEX (Gr. *skolēx*). The embryonic stage of the Tape-worm, formerly known as a 'Cystic Worm.'

SEPIOSTAIRE. The internal shell of the Cuttle-fish, commonly known as the 'cuttle-bone.'

SEPTA. Partitions.

SERTULARIDA (Lat. *sertum*, a wreath). An order of *Hydrozoa*.

SESSILE (Lat. *sedo*, I sit). Not supported upon a stalk, or peduncle; attached by a base.

SETÆ (Lat. bristles). Bristles, or long stiff hairs.

SETIFEROUS. Supporting bristles.

SETIGEROUS (=Setiferous).

SETOSE. Bristly.

SILICEOUS (Lat. *silex*, flint). Composed of flint.

SINISTRAL (Lat. *sinistra*, the left hand). Left-handed; applied to the direction of the spiral in certain shells, which are said to be 'reversed.'

SINUS (Lat. *sinus*, a bay). A dilated vein or blood-receptacle,

SIPHON (Gr. *siphon*, a tube). Applied to the respiratory tubes in the *Mollusca*; also to other tubes of different functions.

SIPHONOPHORA (Gr. *siphon*; and *phero*, I carry). A division of the *Hydrozoa*, comprising the Oceanic forms (*Calycophoridæ* and *Physophoridæ*.)

Siphonostomata (Gr. *siphon*; and *stoma*, mouth). The division of *Gasteropodous Molluscs*, in which the aperture of the shell is not 'entire,' but possesses a notch or tube for the emission of the respiratory siphon.
Siphuncle (Lat. *siphunculus*, a little tube). The tube which connects together the various chambers of the shell of certain *Cephalopoda* (e.g. the Pearly Nautilus).
Sipunculoidea (Lat. *siphunculus*, a little siphon). A class of *Anarthropoda* (*Annulosa*).
Somatic (Gr. *soma*, body). Connected with the body.
Somatocyst (Gr. *soma*; and *kustis*, a cyst). A peculiar cavity in the cœnosarc of the *Calycophoridæ* (*Hydrozoa*).
Somite (Gr. *soma*). A single segment in the body of an Articulate animal.
Spermarium. The organ in which spermatozoa are produced.
Spermatophores (Gr. *sperma*, seed; and *phero*, I carry). The cylindrical capsules of the *Cephalopoda*, which carry the spermatozoa; sometimes called the 'moving filaments of Needham.'
Spermatozoa (Gr. *sperma*, seed; and *zoön*, animal). The microscopic filaments which form the essential generative element of the male.
Spicula (Lat. *spiculum*, a point). Pointed needle-shaped bodies.
Spinnerets. The organs by means of which Spiders and Caterpillars spin threads.
Spiracles (Lat. *spiro*, I breathe). The breathing-pores, or apertures of the breathing-tubes (tracheæ) of Insects.
Splanchnoskeleton (Gr. *splagchnon*, viscera; *skeletos*, dry). The hard structures occasionally developed in connection with the internal organs or viscera.
Sponge-particles. (*See* Sarcoids.)
Spongida (Gr. *spoggos*, a sponge). The division of *Protozoa*, commonly known as Sponges.
Spores (Gr. *spora*, seed). Germs, usually of plants; in a restricted sense, the reproductive 'gemmules' of certain Sponges.
Sporosacs (Gr. *spora*, seed; and *sakkos*, a bag). The simple generative buds of certain *Hydrozoa*, in which the medusoid structure is not developed.
Statoblasts (Gr. *statos*, stationary; *blastos*, bud). Certain reproductive buds developed in the interior of *Polyzoa*, but not liberated until the death of the parent organism.
Steganophthalmata (Gr. *steganos*, covered; and *ophthalmos*, the eye). Applied by Edward Forbes to certain *Medusæ*, in which the sense-organs ('marginal bodies') are protected by a sort of hood. The *Steganophthalmata* are now separated from the true *Medusidæ*, and placed in a separate division under the name *Lucernarida*.
Stellerida (Lat. *stella*, star). Sometimes employed to designate the order of the Star-fishes.
Stelliform. Star-shaped.
Stemmata (Gr. *stemma*, garland). The simple eyes, or 'ocelli,' of certain animals, such as Insects, Spiders, and Crustacea.
Sternum (Gr. *sternon*). The breast-bone.
Stigmata. The breathing-pores in *Insects* and *Arachnida*.
Stolon (Gr. *stolos*, a sending forth). Offshoots.—The connecting processes of sarcode, in *Foraminifera*; the connecting tube in the social *Ascidians*; the processes sent out by the cœnosarc of certain *Actinozoa*.
Stomapoda (Gr. *stoma*, mouth: and *pous*, foot). An order of *Crustacea*.
Stomatode (Gr. *stoma*). Possessing a mouth. The *Infusoria* are thus often called the Stomatode *Protozoa*.

Strepsiptera (Gr. *strepho*, I twist; and *pteron*, wing). An order of Insects, in which the anterior wings are represented by twisted rudiments.

Strobila (Gr. *strobilos*, a top, or fir-cone). The adult tape-worm with its generative segments or proglottides. Also applied to one of the stages in the life-history of the *Lucernarida*.

Styliform (Lat. *stylus*, a pointed instrument; *forma*, form). Pointed in shape.

Sub-calcareous. Somewhat calcareous.

Sub-central. Nearly central, but not quite.

Sub-pedunculate. Supported upon a very short stem.

Sub-sessile. Nearly sessile, or without a stalk.

Suture (Lat. *suo*, I sew). The line of junction of two parts which are immovably connected together. Applied to the line where the whorls of a univalve shell join one another; also to the lines made upon the exterior of the shell of a chambered *Cephalopod* by the margins of the septa.

Swimmerets. The limbs of *Crustacea*, which are adapted for swimming.

Synapticulæ (Gr. *sunapto*, I fasten together). Transverse props sometimes found in Corals, extending across the loculi like the bars of a grate.

Systole (Gr. *sustello*, I contract). Applied to the contraction of any contractile cavity, especially the heart.

Tabulæ (Lat. *tabula*, a tablet). Horizontal plates or floors found in some corals, extending across the cavity of the 'theca,' from side to side.

Tactile (Lat. *tango*, I touch). Connected with the sense of touch.

Tæniada (Gr. *tainia*, a ribbon.) The division of *Scolecida* comprising the Tape-worms.

Tænioid (Gr. *tainia*; and *eidos*, form). Ribbon-shaped, like a tape-worm.

Tectibranchiata (Lat. *tectus*, covered; and Gr. *bragchia*, gills). A division of *Opisthobranchiate Gasteropoda* in which the gills are protected by the mantle.

Tegumentary (Lat. *tegumentum*, a covering). Connected with the integument or skin.

Telson (Gr. *telson*, a limit). The last joint in the abdomen of *Crustacea*; variously regarded as a segment without appendages, or as an azygos appendage.

Tergum (Lat. for back). The dorsal arc of the somite of an Arthropod.

Terricola (Lat. *terra*, earth; and *colo*, I inhabit). Employed occasionally to designate the Earth-worms (*Lumbricidæ*).

Test (Lat. *testa*, shell). The shell of *Mollusca*, which are for this reason sometimes called '*Testacea*;' also the calcareous case of *Echinoderms*; also the thick leathery outer tunic in the *Tunicata*.

Testaceous, provided with a shell or hard covering.

Testis (Lat. *testis*, the testicle). The organ in the male animal which produces the generative fluid or semen.

Tetrabranchiata (Gr. *tetra*, four; and *bragchia*, gill). The order of *Cephalopoda*, characterised by the possession of four gills.

Thalassicollida (Gr. *thalassa*, sea; and *kolla*, glue). A division of *Protozoa*.

Theca (Gr. *theke*, a sheath). A sheath or receptacle.

Thecosomata (Gr. *theke*; and *soma*, body). A division of *Pteropodous Molluscs*, in which the body is protected by an external shell.

Thread-cells. (*See* Cnidæ.)

Thysanura (Gr. *thusanoi*, fringes; and *oura*, tail). An order of Apterous insects.

Tracheæ (Gr. *tracheia*, the windpipe). The breathing tubes of insects.

TRACHEARIA. The division of *Arachnida* which breathe by means of tracheæ.

TREMATODA (Gr. *trema*, a pore). An order of *Scolecida*.

TRICHOCYSTS (Gr. *thrix*, hair; and *kustis*, a cyst). Peculiar cells found in certain *Infusoria*, and very nearly identical with the 'thread-cells' of *Cœlenterata*.

TRILOBITA (Gr. *treis*, three; and *lobos*, a lobe). An extinct order of *Crustaceans*.

TRITOZOÖIDS (Gr. *tritos*, third; *zoön*, animal; and *eidos*, form). The zoöid produced by a deuterozoöid; that is to say, a zoöid of the third generation.

TROCHAL (Gr. *trochos*, a wheel). Wheel-shaped; applied to the ciliated disc of the *Rotifera*.

TROCHOID (Gr. *trochos*, a wheel, and *eidos*, form). Conical with a flat base; applied to the shells of *Foraminifera* and *Univalve Molluscs*.

TROPHI (Gr. *trophos*, a nourisher). The parts of the mouth in insects, which are concerned in the acquisition and preparation of food. Often called 'instrumenta cibaria.'

TROPHOSOME (Gr. *trepho*, I nourish; and *soma*, body). Applied collectively to the assemblage of the nutritive zoöids of any *Hydrozoön*.

TRUNCATED (Lat. *trunco*, I shorten). Abruptly cut off; applied to univalve shells the apex of which breaks off, so that the shell becomes 'decollated.'

TUBICOLA (Lat. *tuba*, a tube; and *colo*, I inhabit). The order of *Annelida*, which construct a tubular case in which they protect themselves.

TUBICOLOUS. Inhabiting a tube.

TUNICATA (Lat. *tunica*, a cloak). A class of *Molluscoida* which are enveloped in a tough leathery case or 'test.'

TURBELLARIA (Lat. *turbo*, I disturb). An order of *Scolecida*.

TURBINATED (Lat. *turbo*, a top). Top-shaped, conical with a round base.

UMBELLATE (Lat. *umbella*, a parasol). Forming an umbel; i.e. a number of nearly equal *radii* all proceeding from one point.

UMBILICUS (Lat. for navel). The aperture seen at the base of the axis of certain univalve shells, which are then said to be 'perforated' or 'umbilicated.'

UMBO (Lat. *umbo*, the boss of a shield). The beak of a bivalve shell.

UMBRELLA. The contractile disc of one of the *Lucernarida*.

UNCINATE (Lat. *uncinus*, a hook). Provided with hooks or bent spines.

UNILOCULAR (Lat. *unus*, one; and *loculus*, a little purse). Possessing a single cavity or chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

UNIVALVE (Lat. *unus*, one; *valvæ*, folding-doors). A shell composed of a single piece or valve.

URTICATING CELLS (Lat. *urtica*, a nettle). (*See* Cnidæ.)

VACUOLES (Lat. *vacuus*, empty). The little cavities formed in the interior of many of the *Protozoa* by the presence of little particles of food, usually surrounded by a little water. These are properly called 'food-vacuoles,' and were supposed to be stomachs by Ehrenberg. Also the clear spaces which are often seen in the tissues of many *Cœlenterata*.

VARICES (Lat. *varix*, a dilated vein). The ridges or spinose lines, which mark the former position of the mouth in certain univalve shells.

VASCULAR (Lat. *vas*, a vessel). Connected with the circulatory system.

VELUM (Lat. a sail). The membrane which surrounds and partially closes the mouth of the 'disc' of *Medusæ*, or medusiform gonophores.

VENTRAL (Lat. *venter*, the stomach). Relating to the inferior surface of the body.

VERMIFORM (Lat. *vermis*, worm; and *forma*, form). Worm-like.

VERTEBRATA (Lat. *vertebra*, a bone of the back, from *vertere*, to turn). The division of the Animal Kingdom, roughly characterised by the possession of a backbone.

VESICLE (Lat. *vesica*, a bladder). A little sac or cyst.

VIBRACULA (Lat. *vibro*, I shake). Long filamentous appendages found in many *Polyzoa*.

VIBRIONES (Lat. *vibro*, I shake). The little moving filaments developed in organic infusions.

VIVIPAROUS (Lat. *vivus*, alive; and *pario*, I bring forth). Bringing forth young alive.

WHORL. The spiral turn of a univalve shell.

XIPHOSURA (Gr. *xiphos*, a sword; and *oura*, tail). An order of *Crustacea*, comprising the *Limuli* or King-crabs, characterised by their long sword-like tails.

XYLOPHAGOUS (Gr. *xulon*, wood; and *phago*, I eat). Eating wood; applied to certain *Mollusca*.

ZOÖID (Gr. *zoön*, animal; and *eidos*, like). The more or less completely independent organisms, produced by gemmation or fission, whether these remain attached to one another or are detached and set free.

ZOÖPHYTE (Gr. *zoön*, animal; and *phuton*, plant). Loosely applied to many plant-like animals, such as Sponges, Corals, Sea-anemones, Sea-mats, &c.

ZOÖSPORES (Gr. *zoön*, animal; and *spora*, seed). The ciliated locomotive germs of some of the lowest forms of plants (*Protophyta*).

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