AN INTRODUCTION

TO

ANIMAL MORPHOLOGY.

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TO

ANIMAL MORPHOLOGY

AND

Systematic Zoology.

BY

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PREFACE.

THE study of Biology in the University of Dublin has been within the last few years greatly encouraged by the introduction of Natural Science into the Undergraduate Course, and by the extension of the means of practical instruction in Zoology and Botany.

In teaching Zoology and Comparative Anatomy, I have found that Students desire to have a text-book in their hands to enable them to learn the terminology of the science, and by giving them a connected view of the varieties of animal forms, to assist them in remembering the practical instruction of the class-room.

There are in English many good works on special provinces in Animal Morphology, and this Manual is not intended to supplant such books, but to fit Students for the profitable perusal of such works as those of Rolleston, Huxley, Flower, &c.

To reduce my lecture notes to a suitable size, I have had to condense many parts to the smallest bulk, and to leave out many matters of detail, such as many of the recent embryological researches of Lankester, Metschnikoff, Kowalewsky, and others.

I regret that, owing to the long time that this work (written in 1873) has been going through the press, I have not been able to introduce into it references to recent discoveries, such as that of the unisexuality and tracheal system of Peripatus, &c.

For the sake of Junior Students, I have printed the chief paragraphs in larger type, the details in smaller, so that the general principles can be more easily grasped.

I make no claim to originality, but have borrowed largely from Gegenbaur, Carus, Haeckel, Huxley, Lankester, Van Beneden, Schmarda, and others. I have endeavoured to avoid the errors of second-hand quotations, and of making extracts from other Manuals, which are easily accessible to Students; and, having been for fifteen years engaged in the practical study of Comparative Anatomy, I have been enabled to verify very many of the statements herein made.

I return my best thanks to Mr. H. W. Mackintosh for his valuable assistance in correcting the press, and to Professor Reynolds for some suggestions in Chapter I.

I regret that some errors have escaped notice in correcting the proofs, the most serious of which is that of Fig. 4, p. 59, which should read Heliophrys variabilis, *Greef*, instead of Heliosphæra radiata, *Sch.*

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INTRODUCTION

TO

ANIMAL MORPHOLOGY

CHAPTER I.

THE group of colloids called Albuminoids is the most complex and unstable series of bodies known to the chemist, and, as we are as yet ignorant of the nature of their apparently definite compounds, we know nothing of their molecular constitution.* The phenomena of life† are always associated with and manifested in a viscid, transparent, colourless, unstable albuminoid, whose two special properties are contractility and the power of converting other Carbon, Hydrogen, and Nitrogen compounds, into a material like itself. An ammoniacal solution of carmine stains it crimson. Of

* Albumen is slightly acid in reaction, and forms compounds with Ba, Ca, Pb, K, Na, &c., the last pair being probably the protein of *Mulder*. *Schwartzenbach* regards its compound with Platino-cyanide of Potassium as being definite, but this is not confirmed by *Diakonow's* analysis.

† Which are motion, cyclical change, the evolution of heat, and the assimilation of other materials. Life is now generally regarded as a mode of energy.

this body (Protoplasm or Bioplasm), white blood corpuscles, the yelk spheres of eggs, the contents of all growing cells, are examples. This substance shows three forms of motion under different conditions :—1st. When diluted with water, internal currents indicated by the circulation of enclosed particles, the outline of the mass being unaltered; a more definite motion than the Brownian cyclosis of non-living fluids, and connected with chemical change. 2nd. Motion attended with change of form, irregular contractions of the whole mass, with temporary protrusions at one part (called pseudopodia), and recessions elsewhere; thus locomotion can take place.* This form of motion may be changed into the first by dilution, or the former into it by the action of a weak (2%) solution of NaCl. 3rd. Ciliary motion,† the protoplasm mass having on its surface constant hair-like processes of its own substance‡ (cilia), rapidly vibrating to and fro, either from within (as in spermatozoa) or from the outer layer of the mass. Long whip-like cilia are called *flagella*, if sub-rigid,

* Thus Amœbæ wander in the waters wherein they live, and white blood corpuscles through the tissues of the bodies of higher animals, as *Waller*, *Recklinghausen*, and *Cohnheim* have described. Such cells are probably used as tissue-pabulum, as *Joung* noticed in connective tissue, *Biesiadecki* and *Pagenstecher* in epithelium, and *Stricker*, &c., in developing embryos.

† *Gegenbaur* regards ciliary motion as different from protoplasmic.

‡ Flagella have been seen changing into pseudopodia in Protomyxa (*Haeckel*) and in Myxomycetes (*De Bary*). The converse, or cilia changing into pseudopodia, occurs in Magosphaera (*Haeckel*). Cilia are never outgrowths from a cell-wall, nor vacuolated nor granular. The granules observed by *Alexander Stuart* in Opisthobranchiata have not been confirmed by others. *Stuart* has also described fine lines passing from the cilia to the cell nucleus, which by contraction moved the nucleus! Probably these are of the nature of the longitudinal striæ found by *Eberth* in cells of ciliated epithelium.

styli. A flagellum originates as a process from the protoplasm mass, which first undulates, then becomes globular, and finally elongates (*Engelmann*). In the formation of a row of cilia the undulating knob elongates into a ridge, which splits into parallel bands, rapidly changing into cilia. The rate of motion of cilia varies per minute from 720* to 480 (*Engelmann*), 190 (*Krause*), 150-100 (*Valentin*).

The effects of reagents on protoplasmic motions are as follows:—1. Very weak alcohol, moderate heat,† and very diluted alkalies favour motions of the 2nd and 3rd form. 2. Ether, strong alcohol, chloroform, stop motions and render the mass granular. 3. Hydrocyanic acid arrests movements. 4. Vegetable alkaloids, as a rule, affect them but little. 5. Weak acetic acid causes irregular contractions, and finally checks motion. 6. Fresh water makes protoplasm masses spherical and develops the first form of motion.‡ 7. Carbonic acid destroys ciliary action (*Kühne*), but the access of air, if resorted to speedily, restores it. 8. Hydrogen checks ciliary action, but cilia thus stopped, if soon exposed to carbonic anhydride, are at first set in motion, and then finally stop (*Engelmann*). 9. Cold checks amœboid motion and rotation of the yelk-spheres, but (if not excessive) only retards, but does not arrest, growth or life-progress. 10. Weak induction currents accelerate amœboid motions or produce contraction (*Kühne*, *Golubew*); they also accelerate ciliary action (*Kistiakowsky*). Every variation of intensity of the current acts as an excitant, producing alternate contractions and relaxations. The closure of a constant current is a stronger stimulus than the opening. Strong currents stop all motions (*Engelmann*).

* I observed this rate in Planaria.

† Moderate heat accelerates the motions of cilia (*Weber*), and the locomotion of corpuscles, which is greatest at 100° F. (*Schultze*). Yelk masses contract and dilate at 90° F. (*Peremeschko*). 113° F. coagulates protoplasm.

‡ The spherical state may be strong contraction (*Kühne*) or rest (*Hermann*).

Protoplasmic motion is sometimes attended with the evolution of gas.* In an atmosphere of Hydrogen and in an oxygenated solution of Hæmoglobin, cilia move until the free oxygen is gone (*Kühne*), but under some conditions vibrations continue for a time without oxygen and without food, as if the mass had in itself a store of energy.

The first stage of decomposition in protoplasm is indicated by the formation of granules, and the disengagement of fluid or gas making little clear spaces (vacuoles). On account of the constantly occurring partial contractions, homogeneous protoplasm masses are rarely of large size, except where feebly acted on by external stimuli; usually they split into smaller particles. The contact of air, of oxygenated water, or other stimuli, seems to cause the surface to undergo chemical change; it ceases to be protoplasm, and becomes a limiting membrane,† through deficiencies in which protoplasmic threads may protrude (cilia?)

As this material is constantly decomposing, new protoplasm needs to be as constantly forming, but its production is often irregular, and may proceed more actively in one spot than elsewhere. Such a spot is usually denser, and takes a deeper carmine dye than the rest of the mass, and is often sharply defined. It is called the nucleus, but it is not essential to growth,‡

* As in Arcella (*Engelmann*). Protoplasm is normally neutral or slightly alkaline, but after exhaustion of motion it is faintly acid, and sometimes weak alkalies revive for a time suspended motions. Possibly the contraction may be the result of the force evolved by oxidation. The contractions in a mass of protoplasm are always partial; one side of a cilium, or one part of a mass contracts, and drags the rest after it. The evolution of light in animals is sometimes attended with the decomposition of protoplasm into urate of ammonia.

† Often porous.

‡ Many cells have no nuclei, as all Monera, Hydrodictyon (Alga), the segmentation spheres of ova, &c.

nor has it any properties other than those of any other particle of vigorous protoplasm.* It may be granular, sometimes vacuolated (*Rollett*), and often has a denser spot within it called the nucleolus. Each independent protoplasm mass is named a plastide; a plastide with no nucleus is a cytode; a nucleated plastide is a cell; a naked cytode is called a gymnocytode; one invested by a membrane is a lepocytode; a naked cell is a gymnocyte (monoplast *Sharpey*); one with a cell-membrane is a lepocyte (*Hæckel*). The largest single cells are the myeloplaxes of growing bones and the muscle cells of Nematodes.

Plastides multiply by gemmation, a bud arising as a small process from a parent cell, then enlarging and becoming detached; by fission, each splitting into two or more nearly equal parts—in this process the nucleus may or may not take part†;—by free cell formation, nuclei arising in a mass of protoplasm, and around each an area of protoplasm becoming isolated by the differentiation of cell-membranes—this occurs in developing embryos;—by endogenous formation, as shown by *Weissmann* in the eggs of Diptera, and by *E. Van Beneden* in the formation of the nucleus in Pseudofilaria of Gregarina gigantea.‡ It occurs pathologically in tumours.

* *Gegenbaur* states that the nucleus differs from the surrounding protoplasm by being non-contractile, but *Böttcher* has demonstrated that a free nucleus or a nucleus removed from a cell contracts actively. *Neumann* describes the nucleus as showing motions in dying cells. Free nuclei may exist in masses of protoplasm.

† *Remak* and *Weiss* have seen cells divide while the nucleus was adherent to one side. The same has been noticed by many other observers.

‡ The multiplication of cells in cartilage, some tumours or ova, is sometimes regarded as of this kind, but in reality it is more likely a concealed form of fission. The instance given by *Buhl* of the formation of

In the simplest animals the protoplasm is homogeneous, but in the more complex the homogeneous yelk protoplasm becomes differentiated in development, and thus we find cells whose contents vary. It has been supposed that protoplasm may be a compound albuminoid resolvable into its elements (myosin, neurin, &c.) in the course of growth; at least two substances may be identified in it, one of which is active and dilates on dilution with water, while the other is not.* All cells are at first protoplasmic, whatever their ultimate contents may be, and protoplasm seems to possess the sum of the properties of the active cells (muscle and nerve) derived therefrom. The chief materials derived from protoplasm in animals I have appended in a note.†

To complete our introductory studies, it may be

pus cells within epithelial is more probably a case of wandering (*Steudeler* and *Volkmann*).

* *Heidenhain* and *Brücke* suppose some cells to have a lacunary structure, with a basis of a more solid albuminoid and a more fluid protoplasm contained therein.

† Protoplasm derivates are of two kinds, Nitrogenous and non-Nitrogenous. The first are:—

Albumen, $C_{72}H_{110}N_{18}SO_{22}H_2O$, soluble in water, not precipitable by alkaline carbonates nor sodium chloride, but is by heat. It varies in property according to its source. Seralbumen (from blood *serum*) is not coagulated slowly by ether. Ovalbumen is, and when injected under the skin of an animal, speedily appears in the urine, which the other does not. The ovalbumen of Raptorial birds is with difficulty coagulated by heat or acid (*Frémy* and *Valenciennes*). In some swimming birds and reptiles the ovalbumen, when diluted, is slowly coagulated by heat.

Globulin is insoluble in water, soluble in sodium chloride, coagulated by heat, changed into acid albumen or *syntonin* by HCl; varieties of it are *Vitellin*, not precipitable by NaCl, when added in substance to saturate its solution; *Myosin* is thus precipitable. *Paraglobulin* or *Fibrinoplastin*, when combined with another albuminoid *fibrinogen*, forms *fibrin*, as in the coagulation of blood.

observed that the following inorganic materials are found in animal bodies :—Oxygen in all the fluids, Hydrogen in the intestinal gases of vertebrates with H_2S, Carbonic acid in all tissues, Calcium Fluoride in bones and corals, Magnesium Fluoride in some corals, Water in all tissues from enamel which contains 0·2 per cent. to the connective tissues of jelly fishes with 99·5 per cent., Sodium Chloride also in all

Peptone is a dialysable form of albumen formed in the process of digestion, not precipitable by heat, dilute acids, nor alkalies.

Fibrin is insoluble in water or NaCl, swells in dilute acids, and this softened form is coagulated on boiling; found in blood.

Casein is probably a mixture of *Alb.* with a non-albuminous substance, which is separated from it in digestion as a dyspeptone; soluble in alkalies, coagulable by mineral acids, precipitable by lime and magnesia salts, insoluble in water or NaCl.

Keratin, the material of the cell-wall in epithelium, resembles casein in many of its properties; it may be a compound of several albumen-derivates.

Gerhardt regards these as similar in composition, but differing in molecular arrangement. *Lebonte* and others regard them as each composed of several radicles united in different proportions. From these are derivable the following nitrogenous non-albuminoids :—

Protagon, present in nerve tissue. A mixture of Cerebrin $C_{17}H_{33}NO_3$, with Lecithin, a body derived from Glycerin $C_3H'''_5$ $\left\{\begin{array}{l} O_1C_{16}H_{31}O \\ O_1C_{18}H_{33}O \\ O_1PO \left\{\begin{array}{l} OH \\ OC_2H_4\,(CH_3)_3\,N_1OH. \end{array}\right. \end{array}\right.$

Leucin C_6H_{11} (NH_2) O_2 present in the tissues of Arthropods, in pancreatic juice, &c. *Tyrosin* $C_9H_{11}NO_3$ found with Leucin and in Cochineal.

Kreatin $C_4H_9N_3O_2H_2O$ in smooth muscle, and with *Kreatinin* $(C_4H_7N_3O)$ in blood and muscle. *Guanin* $C_5H_5N_5O$ in Cestodes and Siphonophora, fishes and birds. *Sarkin* in the muscles of hares and ruminants. *Xanthin* $C_5H_4N_4O_2$, and *Urea* $CO\left\{\begin{array}{l} NH_2 \\ NH_2 \end{array}\right.$ and *Uroxanthin* in urine. *Chlorophyll* $C_{16}H_{20}N_2O_5$ in Turbellaria and some green annelids. *Mucin* in mucus, connective tissue, synovia. *Limacin* and *Helicin* are two varieties of it in the slime of Mollusca. *Collagen*, in the intercellular substance of fibrillar connective tissue is converted into *Gelatin* by boiling water or boiling

tissues, Calcium Carbonate either in a crystalline or nodular form, usually the latter, in forms similar to those assumed by it in deposits from viscid solutions (see *Harting*, Verhandelingen der Koninklijke Akad., Amsterdam, 1873, 13 Deel, p. 4), Nitrogen in the swim-bladder of fishes, &c., Hydrochloric acid in the gastric juice, Sulphuric acid in the saliva of Dolium galea, &c.

dilute acids, gelatinizing on cooling, precipitable by alcohol, corrosive sublimate, &c.

Chondrin, formed by boiling chondrogen, which forms the hyaline basis of cartilage, $C_{16}H_{26}N_2O_7$ precipitable by acetate of lead, alum, but not by mercuric chloride.

Ossein from the intercellular substance of bone resembles Gelatin in most of its properties, but is more soluble.

Elastin from yellow elastic tissue is insoluble in water, alkalies, and most reagents, except strong solution of Potass.

Spongiolin, allied to Keratin, is the element making the horny skeleton of sponges.

Conchiolin, allied to Gelatin, is the animal element in the shells of Mollusca.

Acanthin, like Spongiolin, is the substance which composes the spicules in some Radiolaria.

Neossin, like Gelatin, is the element of which the Edible Birds' nests are made.

Chitin, the indurating material of the integument of Arthropods, $C_{12}H_{26}N_2O_{11}$ insoluble in all ordinary reagents, except in strong mineral acids.

The non-nitrogenous elements are fats, which consist of the following :—

$$\text{Stearin } C_3H'''_5 \left\{ \begin{array}{l} O.C_{18}H_{35}O \\ O.C_{18}H_{35}O \\ O.C_{18}H_{35}O \end{array} \right.$$

$$\text{Olein } C_3H'''_5 \left\{ \begin{array}{l} O.C_{18}H_{33}O \\ O.C_{18}H_{33}O \\ O.C_{18}H_{33}O \end{array} \right.$$

$$\text{Palmitin } C_3H'''_5 \left\{ \begin{array}{l} O.C_{16}H_{31}O \\ O.C_{16}H_{31}O \\ O.C_{16}H_{31}O \end{array} \right.$$

These are derived from glycerin $C_3H''_5 \left\{ \begin{array}{l} OH \\ OH \\ OH \end{array} \right.$ by the substitution of acid radicles for hydrogen.

We know little regarding the genesis of any of the albuminoids or of the conditions under which protoplasm is formed. Analogy favours the possibility of the artificial formation of this substance, as we can form fibrin, casein, &c., from their isomeric relatives. This hypothetic production of protoplasm is called *Abiogenesis* or *Archebiosis*. Experiments* on this point have been made by exposing albuminous infusions to high temperatures, and then hermetically sealing them in vessels. In the course of time minute plastides have been found herein, which are called, if straight, Bacteria, if coiled, Vibriones and Spirilla. If Bacteria be destroyed by a heat of 140° F., and if the fluid have been raised above this point, the reasoning is that the subsequently developed plastides are formed by Abiogenesis; but *Cohn* has shown that in clumps Bacteria may escape destruction even at a

It was long supposed that another body, to which the name Margarin was given, existed in animal fats, but its presence in such fats is doubtful.

Some special fats are Beeswax, which consists of melissyl palmitate ($C_{30}H_{61}$, $C_{16}H_{31}O_2$), cerotic acid $HC_{27}H_{53}O_{22}$, and cerolein.

Butters from milk contain olein, palmitin, butic acid ($HC_{20}H_{39}O_2$), and Butyric acid ($HC_4H_7O_2$), and sometimes other acids with glycerin.

Spermaceti or cetin consists of cetyl palmitate $C_{16}H_{33}$, $C_{16}H_{31}O_2$, and yields on saponification an alcohol-like body named Ethal $C_{16}H_{331}OH$.

Cellulose $C_6H_{10}O_5$ is found in the mantles of Tunicates. *Starch* exists in some Infusoria. *Glucose* is found in insect secretions, &c. *Inosite*, in flesh; *Lactose* $C_{12}H_{22}O_{11} + H_2O$, in milk; *Trehalose* $C_{12}H_{22}O_{11} + 2H_2O$ in the larva of Larinus nidificans; *Scyllite*, in shark's flesh; *Glycogen* ($C_6H_{10}O_5$), in the liver. Besides these are numerous other principles, components of secretions in several glands.

* The conditions of the development of life in such experiments are :—An albuminoid fluid, moderate heat, oxygen and light. Even a partial vacuum does not prevent the formation of bacteria. *Bastian* found bacteria in a sealed solution of ammonic phosphate and sodic phosphate, and of antimonic potassiotartrate.

higher heat, and *Calvert* has shown the same regarding Vibriones. Many of these experiments indicate the existence of some hidden fallacy, as the organisms produced are by no means the lowest, but comparatively complex. The hypothesis that every protoplasm mass is the produce of a pre-existing protoplasm is known as Biogenesis or Panspermism.

CHAPTER II.

GENERAL MORPHOLOGY.

PLASTIDES continuously grouped form *tissues*, which vary according to the nature of their components and of their intercellular substance. The fusion of cells within a common investment constitutes the simplest tissue (Cytocormi, possibly the condition in some Protozoa). Continuous groups of similar cells (each with its own wall) constitute homoplastic tissues, as simple cartilage, hair, cuticle, &c.; if the cells be dissimilar, or if the intercellular substance be abundant, they form a heteroplastic tissue,* as connective tissue, muscle, nerve, &c. Each set of heteroplasts may make an entire animal (as in some Radiolaria), or in the body of a more complex animal they form an *organ-system* (as the dermal, skeletal, muscular, &c.), and these systems are part of a more complex functional grouping or *apparatus*, as the locomotory (of the muscular and osseous systems), circulatory, respiratory, &c. The grouping of heteroplastic organs

* Heteroplasty is the method whereby physiological division of labour is accomplished.

into systems is morphological, into apparatuses, physiological.

The simplest animals are plastides or homoplastic aggregates. In higher forms greater differentiations occur, and when heteroplasts are grouped into organ-systems, these are generally symmetrically arranged, similar heteroplasts being placed side by side around a horizontal axis. Thus a star-fish consists of segments or groups of organ-systems, each built upon the same plan, placed radially around a centre. Such segments may be called *antimeres* (*Haeckel*). They vary in number: each segment of a bilaterally symmetrical animal (Vertebrate or Arthropod) has two; some Radiolaria, three; Medusæ, four; many Echinoderms, five; Zoantharia, six; Luidia, seven; Ctenophora, eight, &c. The increase of a function may be provided for by a multiplication of organs, or a more complicated development in those already existing. Of these methods the former seems the simpler, hence the next step in complexity is the formation of a chain of similar groups in succession. To each element in this chain is given the name *metamere*. These segments may be similar, as in the case of the zonites of a worm, or else some may be specialized. The whole chain constitutes a *persona*,* in which the metameres are usually successional (catenated), or else lateral (fruticose). The highest degree of aggregation in the animal kingdom is the *colony*, in which a number of personæ are united on a common stem as among the compound Hydrozoa.

* The name *persona* may be given to one of the component elements of a colony, whether it be built up of metameres or no, although strictly it should be limited to such as are so composed.

In comparing one persona with another, we call such parts *homologous* as are of equal morphological value, so that if the two compared forms were descendants from a common parent, the homologous parts would be developed from the same parts of the embryo; thus the wing of a bird and the fore-limb of a horse are homologous. Homologies may be complete or incomplete, according as the organs compared are in whole, or in part only, the equivalents of each other. Thus the humerus of man and that of the frog are completely homologous, while the heart of a fish and that of a man are incompletely so. In comparing different metameres of the same persona, corresponding parts are said to be homodynamic (homotypical, or serially homologous); thus fore and hind limb are homodynamic parts. In comparing different antimeres of each metamere, the corresponding parts are said to be symmetrical. In each antimere, if organs are repeated, the repetitions are called homonomous; thus the fingers and toes of the extremity are homonomous segments. Parts which resemble in function, but having no necessary structural relationship, are said to be analogous; thus the lungs of a bird and the gills of a fish agree in function, but are in no sense homologous. The wings of insects and of birds are likewise analogues, but not homologues.

The science which treats of the form, structure, and arrangements of parts in animals, and the laws pertaining thereto, is called Morphology. The science which deals with the functions, actions, and properties of parts is called Physiology. In the following pages the animal kingdom is viewed from a morphological standpoint.

CHAPTER III.

HISTOLOGY.

THE tissues formed by the grouping and differentiation of cells may be classified as vegetative or passive tissues (connective and epithelial), and animal or active tissues (nerve and muscle). The action of the same forces which in a simple cell cause the formation of a cell-wall, in a mass of cells causes differentiation of the surface plastides into an *epithelium*, whose component cells have more or less thick, keratine walls. When adherent together so as to form a porous lamina, this is called *cuticle*, and in it the cell elements may not be recognizable.* Cells on a surface exposed to vertical pressure, or to the drying influences of the air, are scale-like† (pavement epithelium); when newly formed and unmodified, they are spheroidal;‡ if laterally compressed, moist, and on a free surface, they are columnar or conical,§ and this form often exhibits a covering of cilia.‖ Under special circumstances, epithelial cells

* The chitinous cuticle of Arthropods can scarcely be recognized as of connected cells, but as far as its development is known it seems to be a chitinization of a thin protoplasm layer.

† As on the skin, lips, tongue. It may be unilaminar (Monoderic) or stratified (Polyderic). Sometimes its cells are spinose, ribbed, or toothed, as on the amnion of the cat (Eberth). When the cells overlap each other they are squamose; when they touch only at their edges they are tesselated.

‡ Found in glands, and in the deep new layers of stratified epithelium as a transitional form.

§ Found in the digestive tract.

‖ Ciliated columnar epithelium occurs in the trachea and bronchi, the Eustachian and Fallopian tubes, &c. Ciliated spheroidal, often flattened, cells occur in the ependyma on the choroid plexus in the human brain. These cells send deep processes from their attached sides. Ciliated tessellated epithelial cells occur in the tympanic cavity of Mammals at the hinder edge of the membrana tympani, and directly behind the attachment of that membran

may be elongated, fibre-like (as in the crystalline lens), branched, ribbed, pigment-holding, or goblet-shaped, as in the mouth of a fish or reptile, the throat of a frog, or in the vertebrate small intestine (except in birds). This variety has an open mouth (stoma) of naked protoplasm, as have some of the ordinary cylinder cells in the stomach of man (*Schultze*), or the mouth may be partially closed by parallel rod-like particles (*Brettauer* and *Steinach*). The body of such a cell (theca) is dilated and then narrows into a pedicle. These cells, as having the thinnest coating, are supposed to be the most active agents in intestinal absorption (denied by *Th. Eimer ;* they are described by *Arnstein* and others, as only altered cylinder ciliated cells).*

In homoplastic animals, the fluid contents of each cell suffice for the physiological requirements of the animal, but growing complexity requires functional division of labour, and some epithelial cells are clustered together for purposes of secretion. These may be on the surface or in a shallow or deep, simple or branched, recess : such a structure is called a gland. The process of secretion may be one of the liquefaction and conversion of the cell contents into the material to be cast off, as in mucous glands, in which on section a distinct layer of metamorphosing cells may be seen with the microscope (Lunula of Gianuzzi). In other cases there is not the direct cell waste.

The second group of vegetative tissues† includes

* The cells of the middle layer of the epithelium in the bladder of some Mammals are tailed, and their processes seem joined to papillary eminence of the connective tissue underlying.

† *His* describes these as parablastic and developed secondarily in the embryo.

connective tissue, cartilage, bone, cornea, dentine, &c., characterized by having ovoid or branching cells in an intercellular substance,* which may contain mucin, collagen, chondrogen or ossein, all of which are morphologically equivalent. In the embryo it appears as a cluster of closely adpressed plastides with feeble cell-walls, and is known as indifferent tissue, as its after development into one or other of the series depends on external influences.

The forms of connective tissue are—1st. Cellular or parenchymatous, consisting of rounded or fusiform cells† with a sparing intercellular substance, sometimes little more than a thick cell-membrane. This simple form occurs in the ectoderm of Cœlenterata, gland parenchyma, the notochord, &c. 2nd. Mucous tissue, masses of oval, spindle, or branched cells with interlacing processes, with a copious intercellular substance containing mucin. This exists in the discs of Jelly fishes, Tunicates and Heteropoda, the gelatine of the umbilical cord of Mammals, &c. 3rd. Retiform or areolar, fine anastomosing, sparingly or non-nucleated fibres, swollen at their junctions, often with amœboid cells in the interspaces. The connective tissue of the vitreous humour of the eye, the investing reticulum of absorbent glands,‡ the tunica adventitia of blood vessels, neuroglia, &c., are of this sort. 4th. Blood and lymph are connective tissues with a fluid intercellular substance containing cells (see p. 32). 5th. Fibrillar tissue, cells with long or reticular processes in fasciculi together with fibres and coiled fibrils around each fasciculus (*Stricker*). The inter-

* Which can be demonstrated by darkening it with a weak Nitrate of silver solution. It is altered protoplasm as shown in bone (*Waldeyer*), cartilage (*Remak* and *Fürstenburg*), connective tissue (*Schultze* and *Beale*).

† As this form includes lymph cells in its interstices, it is called cytogenous (*Kölliker*), or adenoid tissue (*His*).

‡ For preserving these cells *Müller's* fluid is one of the best media. It consists of bichromate of potass 2½ parts, sulphate of soda, one part, and distilled water, 100 parts.

cellular structure may be white, inelastic, containing mucin, acted on by heat, acetic acid, and liquor potassæ; or yellow, elastic, and resisting most reagents. The white form exists in tendons, fasciæ, ligaments, the basement of serous membranes in all Vertebrates. Among invertebrates it exists in Molluscs, especially in Cephalopods, in Arthropods,* Worms (*Reichert*), and Echinoderms (*Leydig*). Yellow tissue occurs in the ligamentum nuchæ and the interlaminar vertebral ligaments, and is confined to vertebrates. Its fibres are at first protoplasmic within,† and continue to grow by the increase of the intercellular deposit on their outer surface. White fibres do not increase in size when once formed. The fibres may be the outgrowths of cells or (in tendons) fibres and cells may be simultaneously formed.‡ Fat is sometimes laid down within the protoplasm of connective corpuscles, especially in the parenchymatous form (*Czajewicz*).§ 6th. Cartilage is a form of connective tissue in which rounded or fusiform, rarely processed (larynx of ox) or stellate (Nautilus, sharks), cells are contained in a rigid chondrinous‖ intercellular matrix. The simplest form parenchymatous cartilage is a mass of cells with little or no matrix; this is found in Geryonidæ and Siphonophora, the gill supports of Chætopods, Limulus,¶ Cephalopods, the notochord, the skeletons of Myxinoid fishes, &c. Hyaline cartilage has a glassy matrix often marked with clear rings round the

* *Schlossberger* denies its presence in Crustacea, as the so-called fibrous tissue in the crab's claw contains no gelatin.

† Nitrate of silver produces a black marking within these fibres (*Recklinghausen*), and their centre takes a carmine dye (*Frey*). *Rollett* could not detect a tubular structure in section, and *Von Wittich* could not stain the interior with indigo.

‡ *Krause* regards the connective tissue corpuscle as connected with the lymphatic system. He describes spindle-shaped elements (Inoblasts) as components in tendons.

§ Sometimes fat cells have no membrane, as in Amphibia. *Flemming* describes fat as laid down in the tunica adventitia of blood vessels.

‖ Young cartilage often does not give the reaction of chondrin.

¶ The cartilage in Limulus contains chitin in its intercellular substance (*Gegenbaur*).

cells,* which are often polynuclear. This exists in the trachea, the articular ends of bones, &c. Fibro-cartilage has a basis of fibrillar tissue containing cartilage cells: in the embryo it begins as hyaline cartilage, but the matrix fibrillates (*Rathke* and *Rabl-Rückhardt*). The quantity of retiform fibrous tissue in the matrix is small in the adult laryngeal and costal cartilages, large in cotyloid ligaments, the clavicular articular crusts of Primates, and in interarticular cartilages. Reticular-fibro cartilage, with a basis of elastic tissue, is found in the external ear, the epiglottis, the processus vocalis of the arytenoid cartilages (*Rheiner*), &c. Calcification takes place in the cartilages of Sharks, &c., by the deposition of lime-salts in the intercellular substance. In Mammals, a layer of calcified cartilage lies at the junction of the ribs and costal cartilages; (reticular cartilage rarely calcifies). In the development of cartilage, nuclei first appear in the protoplasm, these multiply, and the tissue divides into cell areas; the cells become surrounded by clear margins: at first there is no matrix, but this develops apparently out of successive concentric cell-capsules.

7th. Bone is a form of connective tissue only found in Vertebrates, consisting of corpuscles† united by branched processes, in a matrix containing ossein and lime salts (Phosphate and Carbonate, with a small quantity of Magnesia, and a trace of Ca Fl). The proportions of animal and earthy matters vary in different species‡ and at different ages.§ The

* These may be split into laminæ by chromic acid. Osmic acid shows the matrix to be traversed by straight striæ (juice canals of *Bubnoff*).

† Rarely, as in some fishes and in dentine, there are no corpuscles but only branching canaliculi or processes.

‡ The proportions in some animals are:—

Man,	Animal matter	= 33	Earthy = 67.	Ox,	Animal	= 31	Earthy = 69.
Lion,	,, ,,	= 27	,, = 72.	Salmon,	,,	= 60	,, = 40.
Cod,	,, ,,	= 34	,, = 65.	Porpoise,	,,	= 35	,, = 64.
Frog,	,, ,,	= 35	,, = 64.	Snake,	,,	= 31	,, = 68.

This variation shows that bone is a mechanical mixture of these elements. By dilute hydrochloric acid we may remove the earthy matter: by burning we may remove the animal portion.

§ The proportions at different ages in Man are—49 per cent. of animal

matrix is arranged in plates* around vascular canals (*Haversian* canals), and is studded with corpuscles† which send processes (canaliculi) in all directions.‡ The lamellæ are pierced at right angles by calcified rods.§ In development sometimes the lime salts are laid down in the intercellular substances, so that the connective tissue corpuscles become bone-cells, but this simple form of bone development is rare. Usually in the ossifying of cartilage the corpuscles first multiply and become arranged in columns. Protoplasmic masses ascend in spaces or canals between these, and vessels from the periosteum shoot into their intervals: then a granular osseous matter is deposited along the vessels so that the groups of corpuscles lie in spaces (primary areolæ) bounded by the spicular growth of the bone substance. At this stage the corpuscles become granular and break up into smaller cell masses, while by absorption the primary areolæ are made to communicate with each other, becoming secondary areolæ filled with a series of granular corpuscles (osteoblasts) and free protoplasm. On the walls of these areolæ are laid down laminæ of homogeneous bone matter (secondary bone formation), in which the floating granular cells are embedded, the spaces occupied by them being called lacunæ, and their processes form the canaliculi. These secondary areolar spaces are traversed by vessels and form *Haversian* canals, or, when larger and irregular, form cancellous or spongy tissue. The primary bone is granular, the secondary is at first homogeneous.

Bone tissue thus formed may be compact, traversed by vascular tubes (*Haversian* canals), or cancellous, with wide

matter in the bones of a child, 33 per cent. in the adult, and 28 in very senile bones.

* The lamellæ may be 1st, around *Haversian* canals; 2nd, intermediate to such *Haversian* systems; or 3rd, Peripheric: the latter are few (*Tomes*). Each lamina consists, according to *Sharpey*, of densely decussated fibres. The intermediate lamellæ are parts of absorbed *Haversian* systems.

† About 800 to a square millimetre in man.

‡ Ending in fine points at the articular ends.

§ The perforating fibres of *Sharpey*, which when decalcified are tubular (*Tomes* and *De Morgan*).

secondary areolæ. In this case the bone columns are usually arranged so as to give the greatest strength consistent with the amount of solid material.*

Within growing bone the unossified nucleated protoplasm, formed by the proliferation of cartilage cells, becomes the marrow, of which there are three kinds: yellow, gelatinous, and red. The first consists of delicate connective tissue, vessels and fat cells, and fills the shafts of long bones in most Mammalia. The second form consists of an abundant translucent tissue (coagulable by acetic acid), and a few free nucleated cells. The third form consists of a stroma of stellate corpuscles entangling lymph cells, and surrounded by a close capillary network of blood-vessels whose calibre is four times greater than that of its feeding arteries. By the proliferation of smaller cells, large colossal (myeloid) cells and polynuclear masses (myeloplaxes) are formed.† In this tissue found in the cancelli of young bone, *Naumann*, *Bizzozero*, and others suppose the red blood corpuscles to be formed. (Red marrow is sparingly present in birds.)

Bones may be long, flat, or irregular; they constitute the sclerome or skeleton. Those developed in the integument are called exoskeletal, those in an internal cartilage basis form the endoskeleton, which consists of—1st, an axial or central column protecting the nervous and visceral systems, and 2nd, an appendicular part, or the skeleton of the limbs. Dermal or integumental bones are developed by ossification in a fibrous matrix (*parostosis*), and have no granular stage. Endoskeletal bones may be developed by *endostosis* (ossification beginning within the intercellular spaces of a cartilage mass), or by *ectostosis* (ossification proceeding from the surface inwards, beginning beneath the *periosteum* or fibrous sheath which surrounds all bones).

* *Meyer* distinguishes two sets of pillars in the cancelli, one set in the line of greatest pressure (pressure lines, Drücklinien), and the other in the lines of traction (traction lines, Zuglinien).

† *Bredichin* describes the colossal cells as formed from bone.

CHAPTER IV.

ANIMAL TISSUES.

MUSCULAR tissue consists of contractile cells. While in the simplest cells the unaltered protoplasm alone is contractile, here the entire cell is so. The simplest muscle cell is fusiform, simple or forked* at its ends, $\frac{1}{300}''$ to $\frac{1}{600}''$ long, with its thickest part not quite central, and containing a rodlike nucleus capped by a pyramidal mass of granules at its ends (*Klebs*). When it contracts, the cell surface shows transverse,† and occasionally longitudinal,‡ striæ. Such cells joined by connective tissue form fascicles of involuntary muscle, such as are found in the intestinal wall of Vertebrates, or in the body wall of all classes, except Arthropoda, from Sponges upwards. Voluntary or striped fibres consist of conjoined contractile cells within a connective [some say elastic] sheath (Sarcolemma), the contractile matter being in discs§ separated by clear interspaces. Each fibre may be split artificially into obliquely inclined transverse discs (cleavage planes) or longitudinal fibrils (consisting of single rows of square sarcous elements, large and small alternately, with clear interspaces).‖ The sizes of

* As in the fibres of the Frog's bladder. Striped muscles ending in the skin divide into pointed fibrils which appear continuous with the processes of the connective tissue corpuscles of the dermis (*Salter*).

† *Meissner.*

‡ *Wagener.*

§ The dark bands (disdiaclasts) consist of granules of a double refracting substance in the general isotropic myosin fluid substance of the fibre.

‖ Intermediate forms exist between the smooth and striped fibres: thus in the involuntary fibres of the bladder *Schwalbe* saw a partial striation, and

fibres may vary : those of the Skate are $\frac{1}{60}''$ in diameter, of Man $\frac{1}{364}''$, of Insects $\frac{1}{419}''$. The lengths of fibres also vary from $\frac{1}{8}''$ to $2''$. Muscular fibres end in tendons, the tendinous material being continued as a sheath on the fibre for a short distance. Every muscle acts from one end which is more or less fixed (origin), on the other end, which is more or less movable (insertion). Muscles may be classified, according to their shapes and the direction of their fibres, into prismatic, penniform, triangular, quadrilateral, sphincteric, ellipsoidal and skew.

The contraction of muscle is attended with chemical change,* heat, the evolution of carbonic acid, and the production of inosite, &c. In higher animals each cubic inch of muscle is capable of giving out a constant amount of work (about 100 foot pounds) in a single contraction. As a rule, the work done by a muscle bears a proportion to its weight, and for each muscle when kept in action until complete fatigue sets in, the total amount of work, multiplied by the rate of work, is constant. The cessation of life in muscle is shown by a continuous stiffness (*rigor mortis*) due to the coagulation of myosin in the inter-fibrillar spaces, which lasts until the insetting of further chemical change, when the cell contents change to syntonin.

Nerve tissue is peculiarly animal, nothing similar having been as yet detected in sensitive plants. Protoplasm, when irritated, contracts, but its modifica-

the heart muscular fibres consist of uniting cells without (or with, *Winkler*) a sarcolemma.

* Muscle when at rest is amphichromatic (alters the colour both of red and blue litmus paper), but when in action it becomes acid. In *rigor mortis* it is also acid.

tions, epithelium, connective tissue, &c., do not. When such elements increase in a heteroplastic body, some sensitive replacement for the primordial protoplasm is necessary: hence cells and fibres are set apart for receiving impressions and conveying irritations. The simplest of such apparatuses are the neuro-muscular cells of Hydra (Fig. 13). Nerve fibres first appear as minute homogeneous bands (primitive fibrils, as in some Cœlenterates and Annuloida). Such fibres are commonly united in longitudinally striated bundles, with scattered nuclei and an inter-fibrillar granular tissue (naked axis cylinders,* as in many Invertebrates). These bundles may be invested with a medullary sheath of a highly refracting oily substance and protagon. On isolation, these fibres break up and become varicose; after death the sheath coagulates. The fibres of the optic and auditory nerves of Mammals are of this kind. These vary from $\frac{1}{2500}''$ to $\frac{1}{1500}''$ in diameter. In the ordinary nerves of all Vertebrates (except Acrania and Marsipobranchii) there is superadded a transparent, structureless, feebly refracting, nucleated, sometimes laminated, connective tissue (nucleated sheath of *Schwann*), very thick in the nerves of Electric Fishes. Bundles of medullated fibres enveloped in a nucleated sheath of *Schwann* form the olfactory nerves of Mammalia, or without such a sheath in the olfactory tract of Sharks. Similar fibres separately enveloped in the connective sheath form the abdominal branches of the sympathetic nerves (*Remak's* fibres) in Vertebrates, and are common in Invertebrates. Among

* *Grandry* describes the axis cylinders as made up of transversely placed discs of one material, with a diverse substance intercalated. *Schultze* says the axis cylinders consist of separate fibrils.

Crustacea the nerves have medullary sheaths. When nerves divide, their sheaths attenuate, but the sheath on small branches is thicker than on larger. On very small branches the sheath of *Schwann* is lost first, then the medullary sheath: then the axis cylinder splits into its component fibrils.

Nerve fibres begin in uni- or multipolar,* finely granular, nucleated, and nucleolated nerve corpuscles (dilatations of the axis cylinders ?) surrounded by a capsule of connective tissue. Clusters of nerve cells embedded in protoplasm and a copious inter-fibrillar matrix are called *ganglia*. Nerves end in different ways:—1. In free ends between epithelial cells (in cornea, *Hoyer* and *Cohnheim*). 2. In pear-shaped bodies (epiglottis, *Klein*) or pyramids of protoplasm with clear elliptic nuclei (testis, *Letzerich*), or in branched gland-cells (?) (*Pflüger*). 3. In sense organs they end in fusiform or rodlike bodies with non-vibratile blunt processes (gustatory cells of *Lovén* and *Key*, the smelling cells of *Schultze*, sentient cells of rete mucosum, *Tomsa*, retinal cones, and *Cortian rods*). 4. In *Pacinian* corpuscles, or dilated bulbs of diverging primitive fascicles surrounded by a finely granular mass of protoplasm, and enclosed in dense concentric laminæ of connective tissue.† Similar club-shaped bodies without the connective capsule are the end organs of *Krause*. The corpuscles of *Meissner* in the sensitive palmar papillæ, are furrowed bodies into which a nerve enters and twines round once or twice, rising to its top. 5. In muscle, nerve fibres end by entering the sarcolemma in little conical eminences (*Doyèrian* papillæ), then breaking up into a wide-meshed plexus of fine filaments which may end in a plate composed of an upper granular layer and

* Each cell may have many poles, but has only one peripheric branch (*Deiters*). Sometimes a spiral filament (or 2, 3, or 4 such, as in the Frog) winds round the straight peripheric branch—two kinds of these, nervous from the substance of the corpuscle, fibrous from a basal network, are described by *Schwalbe*.

† Bodies like *Pacinian* corpuscles, arranged in chains on an axis band, exist in the tympanum between the pyramid and the canal for the tensor tympani muscle, as well as in the mastoid cells.

a lower homogeneous surface made of the expanded axis cylinder. This lies on a layer of granular protoplasm lying directly in contact with the disdiaclasts, or no granular layer may interpose (Frog). In electric and pseudelectric plates, nerves end in a similar manner. *Hensen* describes nerves as ending in the nucleoli of epithelial cells in frog skin; *Lippmann*, in the nuclei of the corneal corpuscles; *Joseph*, in the nuclei of bone corpuscles.

Nerves when living are weakly alkaline, or neutral.* After death, or when heated, they become acid; during action they take in oxygen and give out carbonic acid (*Ranke*). Impressions travel along nerves at the rate of 111 feet per second† (*Helmholtz* and *Baxt*), nearly the same rate as that of a sound wave through a material of equal density.

CHAPTER V.

TECTOLOGY.

ANIMALS, as distinguished from plants, are living beings whose nitrogenous form-elements are continuously united (not separated by partitions of ternary compounds), assimilating organic matter only,‡ ab-

* Constant electric currents make nerves acid at the anode, but unchanged at the cathode.

† *Donders* states the rapidity of feeling as $\frac{1}{7}''$, of hearing $\frac{1}{8}''$, of sight $\frac{1}{3}''$. In each of these and the consequent muscular action there are the following stages:—1. Action on the percipient element; 2. communication to nerve ganglion cell; 3. increased action in this cell; 4. conduction to sensorium: 5. action in sensorium; 6. action of volition; 7. conduction to motor cells; 8. action in these cells; 9. conduction to muscle; 10. action of muscle. The psychical part he supposes to occupy about 0.06″.

‡ Like all organic beings devoid of green chlorophyll, such as Saprophytes.

sorbing oxygen, and evolving carbonic acid. Muscle and nerve exist only in them, as are the more complex forms of connective tissue. *Haeckel* proposes to make a third kingdom, Protista,* of a series of living beings intermediate between plants and animals. But most of these, though not falling in rigidly with the definition of either, have recognizable affinities pointing to one group or the other, and as the limits of every class are arbitrary, it is easier to draw one line of demarcation than two: hence I have not adopted this arrangement.

The animal kingdom, as it presents itself to us, is a vast assemblage of individual forms. Individual may be used as a physiological or as a morphological term; in the former sense it means a single form enjoying independent life for a longer or shorter time, in the latter, a single form which is in itself an indivisible whole, whose parts are integral. Sometimes the morphological individuality is a matter of difference of opinion, as among Sponges. *Dr. Carpenter's* definition of an individual (the total product of a single fertilized ovum) is inapplicable to most of the Protozoa and confusing in discontinuous colonies, but yet with a more perfect knowledge, doubtless it will be found to be nearest to the truth. A morphological

* This kingdom, if recognised, would contain nine classes:—1. Monera, composed of cytodes; 2. Protoplasta of cells, divided into Gymnamœbæ, Lepamœbæ, and Gregarinæ (all these have animal affinities); 3. Diatomaceæ, with siliceous shells, generally regarded as unicellular Algæ; 4. Flagellata, a mixed group, some probably vegetal, others certainly animal; 5. Myxomycetæ, a most problematical group, with affinities to Fungi, but even stronger relations to Protozoa; 6. Labyrinthulea, animals; 7. Phycochromacea; 8. Fungi, both usually regarded as vegetal; 9. Radiolaria.

individual may be a plastide, an organ, an antimere, a metamere, a persona, or a colony, and hence we speak of individuals of the 1st, 2nd, 3rd, 4th, 5th, or 6th orders. Individuals of the 3rd to 6th degrees consist of organs the study of whose mode of grouping is the science of Tectology. Organs may be classified, according to their functions, into:—1. Assimilative; 2. Nutritive; 3. Depuratory; 4. Relational; and 5. Propagative. In plastides the protoplasm fulfils all these functions. With increasing complexity comes a division of physiological labour and a localization of function, which is termed differentiation, and seems due to the segregation of some of the compound radicles which make up protoplasm, myosin separating in one group of cells, forming muscle, protagon, and myelin, in others forming nerve, &c.

Relational organs appear first to be differentiated in the form of an integument; indeed, the cell-wall in plastides is of this nature. In groups of cells the outer plastides harden into epithelium, and sometimes in these cells, or even in the walls of a plastide, carbonate of lime (Foraminifera) or silica (Radiolaria) becomes deposited as a shell. Sometimes in plastides or groups of plastides these substances are deposited as spicula within the texture for purposes of support.*

In higher forms a layer of connective tissue forms under the epithelium constituting a dermis, from protoplasm exuded on whose surface the epithelium is renewed. In such cases the epithelium is moulded to the secreting surface.

* These deposits are formed in obedience to ordinary molecular forces, as these mineral elements assume the same forms in viscid fluids, as proved by the researches of *Max Schultze*, *Rainey*, *Harting*, &c.

The hardening of the outer surface interferes with the general secretory nature of the surface, and hence in recesses, spheroidal epithelial cells are set apart for this, forming glands. Hardening likewise interferes with the general sensibility of the surface, and hence special processes, tentacles, &c., are developed. Lime salts or chitin may be deposited in the surface cells, forming shells, or in deeper tissues, as in Corals and Echinodermata, or these may ossify, as in the exoskeleton of Vertebrates.

In simple individuals the only vibrations necessary to be recognised for the purposes of the organism are those caused by material contact or heat. In complex forms, means for the detection of the finer vibrations are provided. For the centralization of perception, the nerve elements are segregated in cells near the end of the body foremost in progression, at the base of special touch organs where such exist, or where the surface is least protected. Around the pharynx these form a single or secondarily double ganglion in each antimere, united to its fellows by a commissural ring, from which nerves pass to the sense organs, to the mouth surface to end in taste cells, and to ciliated cavities possessing the sense of smell. The multiplication of metameres is attended with an extension of the nervous system, on the inferior side of the viscera as a twin cord, with ganglia in each metamere. The enlargement of the upper element of the pharyngeal ring forms a brain, and in Vertebrates this part of the nervous system is prolonged backwards on the upper side of the viscera as a spinal cord. As organs for receiving impressions and acting on stimuli increase, so the brain mass increases and differentiates,

and processes connected with it (nerves) permeate the textures. To recognize sound waves a vesicle full of fluid containing a calcareous body (Otolith) is developed, to which passes a nerve from the central system. Such organs of hearing are widely distributed.

They occur in Medusæ, in many Worms in which they are placed usually near the cephalic ganglion, in some Turbellaria, where they are unsymmetrical, sometimes single, while in parasites they are absent.

In Tunicates there is an unsymmetrical ear vesicle; in Brachiopods it is only present in the larva; in Lamellibranchs the vesicles are close to the pedal; in Cephalophora, to the pharyngeal ganglion; in Cephalopoda they are cephalic, and either simple vesicles (Octopus), or a more complex labyrinth, both ligamental and cartilaginous, with single or multiple otoliths.

To appreciate light, we find in Infusoria, &c., brightly-coloured pigment spots or photoscopic eyes, sometimes separate from the nervous system (which may discriminate light from darkness). More definite eyes exist in Annulosa as crystal rods or cones at the end of a nerve surrounded by pigment. A cluster of these may form a single mass (Sagitta, &c.) In higher Arthropods a new element is added, for the chitinous integument over the cones is clear, free from pigment, and transparent, lenslike forming a lenticular cornea.

Single eyes of this form exist in Corycæa, &c., but commonly they are in clusters forming compound eyes, as in Insects. In such eyes the optic nerve ends in a granular ganglion, in which the ends of the rods are imbedded; around these is the pigment mass, and over the end of each is a separate corneal lens. As these are closely clustered, each facet becomes hexagonal. These groups are called facetted eyes, and from 3 to 8,000 may be in each cluster. Sometimes the surface is smooth, and the facetting is only

seen within, as in Crustacea. In Arachnida there is only one corneal lens for a number of crystal cones, and the same occurs in the stemmata or single eyes of Insects. In some Spiders there are muscular (iridal ?) fibres among the pigment, and a rudimentary reflector or tapetum. Sometimes in Crustacea, muscular fibres exist capable of drawing the cornea to the cones, a rudimentary accommodating apparatus. These eyes capable of receiving and recognizing images are called Idoscopic (*Jourdain*).

The lowest animals live in water, hence pseudopodia or cilia are sufficient means of locomotion. Some Gregarinæ have a special contractile layer like the axis of the stalk of Vorticella. Definite muscular fibres appear in Hydrozoa, first as processes from the neuro-muscular cells of Hydra attached to the ectoderm, and these become arranged in strata. With antimeral growth, muscle bands assume a symmetrical, and with metameral, a homodynamic symmetry. When appendages form from the axis they have special bands of these strata attached to them, and thus a muscular system grows in complexity. Each muscle carries its proper nerve, so the peripheral nervous system grows *pari passu*. According as the muscle is attached to the dermis or to the inner connective tissue, it is called exo- or endo-skeletal. The endoskeleton itself first appears as a fibrous or cartilaginous investment of the digestive and sense organs in Molluscs, but is fully developed in Vertebrata.

The assimilative organs are differentiated next to the relational. A naked plastide can take in and digest food and eject effete particles at any part of its mass, but the formation of a cuticle renders the presence of a mouth necessary. This appears first in ciliated Infusoria, and may open directly into the

protoplasm of the plastide or cytocorm, or by means of a funnel and wide passage, which sometimes narrows into a tube (Œsophagus). Polystomata, &c., have an internal cavity added, and in Cœlenterates we find this lined by separate cells,* which secrete a special fluid by which the food is dissolved†, and the nutritive part transuding the plastides of the walls nourishes the animal. Effete matters are ejected either at the mouth or by a special opening at the distal end (anus). An elongation of the communication between the stomach and anus to increase the absorbing surface forms an intestine from which, for the same purposes, blind pouches (cæca) may project. Secondary appendages for the prehension and mechanical division of the food (jaws and teeth), for the moistening of the food in deglutition (salivary glands‡), and for the assimilation of fats (liver and pancreas§), are afterwards developed in and from the tube.

* The development of an internal cavity is regarded by *Haeckel* as distinguishing the second or gastræa type of structure from the primitive planula form.

† Gastric juice contains in higher animals water, pepsin (an albuminoid), hydrochloric, butyric, and lactic acids, and phosphates of soda and lime, &c. It converts albuminoids into dialysable forms (peptone, metapeptone, parapeptone, &c.) by making them take up water.

‡ Saliva, the secretion of the parotid, contains water, ptyalin (an albuminoid), albumin, mucin, sulpho-cyanide of potassium, a fatty acid, and salts of potass, soda, lime, &c. This fluid can saccharize starch in neutral alkaline or weakly acid solutions. The secretion is mainly poured out under the agency of stimuli, food, odours, &c. Other glands, submaxillary, sublingual, buccal, labial, &c., are mucous glands pouring fluid into the mouth. The secretion of the first of these acts feebly in saccharizing starch. These secretions are but slightly influenced by the smell of food, but are actively affected by the movements of mastication.

§ The liver secretes bile, an orange or yellow alkaline bitter fluid containing water, cholesterin (a crystalline fat $C_{54}H_{94}O_2$), sodic glychocholate.

The alimentary canal may be the only body cavity, or it may be suspended in a larger separate cavity (Cœloma) formed either by outgrowing spaces from itself (Ctenophora, Echinodermata, &c.), or by invagination (Amphioxus), or by the splitting and separation of two mesoblastic layers.

In simple animals the nourishment is taken into the plastides of the stomach wall, but as these walls become membranous, and as other organs become more complex, the assimilated fluid collects in separate spaces where, by osmose or the general contraction of the body wall, or by a special contraction of a muscular tube, it is made to move so as to bathe the tissues. This newly-formed system is the nutritive or circulatory. At first, as in Actinozoa, with a body cavity (distinct from the stomach), it is in this space that the nutritive fluid, mixed with water, is to be found. In the lower Worms, where the digestive and perivisceral spaces do not communicate directly, the body cavity still contains the nourishing fluid, which yet often contains sea water. In the higher Annulosa definite vessels exist, but yet in some the blood only traverses these for a limited part of its circulation, as at each end they often freely communicate with the perivisceral spaces. In some Arthropods and Molluscs

and taurocholate, bilirubin ($C_{16}H_{18}N_2O_3$), biliverdin ($C_{16}H_{20}N_2O_5$), as pigments. In pigs the bile contains hyocholic and hyocholeic acids, in ox gall, taurine (C_2HNSO_3). Glycocholic acid is $C_{26}H_{45}NO_6$, taurocholic, $C_{26}H_{45}NSO_7$. Bile precipitates peptones. In the gall bladder the bile is thickened by the addition of mucin. The bile is largely excrementitious, but also is an agent in saponifying fats. The pigments are formed of altered hæmoglobin. The pancreas secretes a fluid containing water, phymatin, salts of soda, &c., tyrosin, leucin, guanin in traces. It emulsifies fats, setting the acids free, and permits their absorption, dissolves albuminoids, saccharizes starch, even in acid solutions.

a closed system of vessels appears, larger vessels traversing the tissues and carrying pure, nutritious blood (arteries), ending in fine capillary vessels, in which this blood acts as a pabulum to the tissues, finally ending in larger vessels (veins), which return the blood impoverished by the loss of some of its nutritious parts, and carrying away the products of tissue-waste. In Vertebrates, this system is still more perfect and better organized. The venous blood requires to be purified and to receive fresh nutritive elements. The first end is accomplished by its being exposed to oxygen, also by its passing in contact with certain gland cells which abstract its impurities.*

* Blood is a connective tissue with a fluid intercellular matrix (called liquor sanguinis) and corpuscular cells. The simplest form of cells are amœboid, sometimes vacuolated or simple, protoplasm : in the higher Vertebrates these co-exist with reddish discoidal corpuscles. These corpuscles have a firm central basis (zooid) composed of the nucleus and hæmoglobin inhabiting the œcoid or disc.

The red corpuscles consist of paraglobulin and haemoglobin, a crystallizable principle which can absorb oxygen and exist in two states, deoxidised (purple cruorin) or oxidised (scarlet cruorin).

The fluid in which the corpuscles float (liquor sanguinis) contains albumen, fibrinogen, fatty matters (serolin, cholesterin, and ordinary fat, phosphates, chlorides, &c.) When blood is exposed to the air, at rest, or under other conditions, the paraglobulin (fibrinoplastin) of the liquor sanguinis and corpuscles unites with the fibrinogen of the plasma, and forms fibrin, which separates from solution, entangling the corpuscles and forming the clot. The fluid part (liquor sanguinis *minus* fibrinogen) is called the serum.

Pure blood in the arteries or in veins returning from the depuratory glands is bright scarlet containing oxidised hæmoglobin, a large quantity of dissolved oxygen, and a small amount of carbonic acid. In the capillaries this blood nourishes the tissues, parts with some of its protoplasm-forming elements and with much of its oxygen, while it takes up urea, inosite, kreatin, and a larger quantity of carbonic acid. Hence venous blood is dark purple (coloured by deoxidised hæmoglobin), contains 6·7 per cent. more carbonic acid, and 9 per cent. less oxygen than the arterial (*Sczelkow*).

The exposure to air takes place in the respiratory organs, of which there are four types—1st. In aquatic animals, the blood, contained in organs called branchiæ (gills), is exposed to water containing oxygen in solution; 2nd. Also in water dwellers, a system of tubes communicating with the external water and traversing the animal's body, admits this fluid so as (through their walls) to aerate the blood in the perivisceral space (water vascular system); 3rd. A system of tubes (tracheæ) containing air, ramifying through the body, whereby the blood may be directly aerated; or 4th. A series of sacs (pulmonary sacs, lungs) set apart for the reception of air, to which the impure blood is brought, and exposed in capillary vessels.*

The glandular depurants remove from the blood the waste of nitrogenized material. They are the dermal glands† (the only ones in the lowest forms), and kidneys.‡

* In the respiratory organs, water, carbonic acid, and traces of other substances are got rid of and oxygen taken in. As this oxygen enters into chemical combination with the protoplasm in the tissues in the life processes, in all living forms heat is evolved during such chemical action, and the amount thereof varies with the activity of the combinations.

† In the perspiration. or excretion of the dermal glands is contained water, sodic chloride, ammonic lactate, butyrate, and acetate, some nitrogenous materials, sometimes formic acid, and an odorous principle.

‡ The kidney separates from the blood, urea, uric acid, often combined with ammonia, kreatin and kreatinin, sometimes hippuric and benzoic acids, xanthin and hypoxanthin, urophæin, and salts similar to those in blood serum.

CHAPTER VI.

REPRODUCTION.

THE organs hitherto referred to deal with the well-being of the individual: for the propagation of the species other apparatuses are needed. The simplest morphological individuals reproduce by discontinuous fission or gemmation. Higher forms show a more complex mode, which, however, still partakes more or less obviously of these primitive methods. In this process two cells co-operate: one organ derived from the endoderm or inner germ layer of the embryo* (the ovary), forms, by gemmation of its component plastides, special cells (ova), which are to be the new individuals. Another often similar organ, but derived from the ectoderm or outer germ layer* (testis), forms elements also from its own plastides, whose function is to unite with and stimulate the ova into development (spermatozoa). What the nature of the stimulation is we know not, and it is as yet idle to theorize, though the diverse origin of the two elements is suggestive. In the simplest cases the organs producing these diverse elements are, though dissimilar in origin, side by side or united, or we may find them at separate parts of the same animal. The ova are nucleated cells; the spermatozoa are nucleated flagellate plastides formed within a mother-cell. If ovaria and testes co-exist in one individual, it is called monoœcious or hermaphrodite. If the sex organs are in separate individuals they are called diœcious. The contents of the sex organs may be emitted by simple rupture (dehiscence),

* *E. Van Beneden.*

or carried by ducts, called respectively oviducts and vasa deferentia. All reproductive processes seem only to differ from growth processes in that the results are discontinuous, and they may be divided into two series—1st. Agamogenesis, where no second or male element is required to stimulate the (often internally produced) germ into development. The simplest form of agamogenesis, leaving out of account fission and gemmation in plastides, is the production of the so-called winter eggs in sponges, where we have a constant and, as far as we know, continuous asexual propagation not necessarily interrupted by any periodic recurrence of sexual reproduction. Such a form is monogenetic agamogenesis, as the progeny and parents are similar. In another case a primary form or protozooid produces, by internal gemmation (without having any developed sexual organs), a secondary form or deuterozooid, and this may in time produce a tritozooid, or it may develop sexual organs and produce ova, which require the male elements to fertilize them. To this process the name *metagenesis* has been given, and of it there are varieties: thus, when the deuterozooid is sexual, and so differs from the protozooid, the process is *metagenesis with successive heterogony*, or if the protozooid be sexual, and by internal gemmation give rise to a deuterozooid in which sex organs are also developed, the *metagenesis* is said to be *with contemporaneous heterogony*, and it may be *isogenetic* or *diverse*, according as the deuterozooid agrees or disagrees with the protozooid in sex. Where there are successions only of two stages, the name *digenesis* is sometimes given in place of metagenesis.

In other cases the protozooids have generative

organs like ovaria, but producing gemmules (more or less resembling true ova), which do not require any male stimulus for their development. These organs are called *pseudovaria*, and the gemmules are viviparously produced. Each of the deuterozooids can produce in these cases *tritozooids*, &c., as long as suitable conditions of temperature and food continue; but on the occurrence of some unknown checks upon this process, the individuals of the last brood develop perfect sexual organs and are oviparous. To this process the name *parthenogenesis*, or more properly *pseudo-parthenogenesis*, is given. The products of the pseudovaria may be eggs, as among the worker Bees, &c., from which usually males are hatched (except in some Wasps). Females with perfect sexual organs, but without the stimulus of spermatozoa, may produce ova, as in the case of Queen Bees, Psyche helix, Solenobia triquetrella, and lichenella, or else embryos may be produced, as in some Cœcidæ, Chermes, &c. 2nd. Gamogenesis is that form in which the female gemmule requires the stimulus of contact with the protoplasm of the male spermatozoon, in order to cause its development. In this case the ovum consists of a cell with a germinal vesicle or nucleus, with a nucleolus or germinal spot.* This is generally included within a yolk (Vitellus), surrounded by a vitelline membrane. Outside this are often layers of albumen and an enclosing shell. There is often a micropyle or opening in the egg-envelopes, whereby the contents may receive the contact of the spermatozoa. On impregnation the yelk shows amœboid motion, loses its germinal vesicle

* Within which may be a vacuole (*La Valette*) or a solid bright spot (*Schrön*).

and spot,* cleaves into two, then into four, then eight, &c., until it is resolved into a morula or mulberry-like mass of cytodes. The cytodes develop nuclei and become cells. This process may involve the whole yelk circumference, as in Mammalia, &c., and the eggs are called holoblastic, the germ and yelk elements being combined, or only a part, as in Birds, and the rest is gradually absorbed as nutriment into the cleaved part (meroblastic ova), the germ and yelk being separate. The sphere of embryo cells produced by the segmentation of the yelk is called the blastoderm, and in all animals above Protozoa this divides into two layers (becoming a planula),† an outer serous or epiblastic, and an inner mucous or hypoblastic, within which forms a cavity (the cleavage cavity or cavity of *Baer*). The embryo in meroblastic eggs is supported on subgerminal processes. Between these layers there forms a mesoblast of one or two laminæ. The after-stages differ in the different classes, and will be considered under each head. Thus all animals in their earliest embryonic stages are identical; but the process of differentiation takes place along diverging lines, and each stage narrows the circle of resemblances, or as *Von Baer* expresses it, development takes place from the general to the special.

Animal forms can be grouped into certain categories called *species*,‡ each consisting of individuals identical

* In Entoconcha, *Müller* describes this as persisting and becoming transformed into the nuclei of the cleavage cells.

† Which by absorption at one pole forms a mouth, and becomes a gastrula.

‡ It is impossible to define *species* to the satisfaction of all naturalists, as the conceptions in their minds are not the same, and species, genus, &c., must be looked on as more or less arbitrary (ideal conceptions).

in all essential characters, leading to the belief that they have descended directly from a common stock. A group of species closely resembling each other in their general characters is named a *genus*. A group of genera bound together by natural affinities is a *family*, a group of allied families, *an order*,* of allied orders a *class*, of allied classes a sub-kingdom, which is the highest category in the predicamental line under the animal kingdom. The embodiment of the special form-characters of any of the categories is called its *type*. Thus we speak of the type of a genus, family, &c. When one type form unites in itself the leading special characters of two or three diverse forms, it is called a synthetic type. Such forms were common in earlier periods of the world's history. Type-forms which retain as characters many of the embryonic features of the entire superior category including them, are called *generalized types*. These are the poorest in species, and the most local in distribution of animal forms. The arrangement of individuals in these categories we know as *classification*, and this is often a matter of difficulty, as no two individuals are precisely alike. In categories of which we have many individuals, connecting links between apparently different forms constantly occur, so that a systematist has either to make a large number of small groups or the opposite (witness the family Helicidæ, and in botany the genera, Hieracium, Rubus, and Salix). We cannot define the exact limits of any species until we know its range of variation, which has never yet been precisely ascertained for any single

* When further divisions are required, we speak of orders being divided into sub-orders, and classes into sub-classes.

species, as we are yet imperfectly acquainted with the palæontological record of past life. On the other hand, the necessity for the union of several so-called species (by the discovery of a perfect series of links) has often occurred in the experience of zoologists.*

In the characters of types, arrangements apparently unconnected with each other always occur in groups: thus, animals that suckle their young have always two occipital condyles and non-nucleated blood corpuscles, and animals clothed with feathers have a muscular right auriculo-ventricular valve. These coincidences are called *correlations of growth*, and can only be intelligently accounted for on the ground of a community of descent.

In tracing the embryonic development of individuals, a retrogression is sometimes noticed instead of a progression. This is the reverse of specialization, and produces a simplification of organs. An animal in a position in which certain organs would be useless, loses them, and thus becomes reduced. Thus, reduction is the consequence of loss of function. It is a gradual process, organs becoming rudimental before they become finally aborted. These rudiments are called by *Gegenbaur*, significant finger-posts in comparative anatomy. Two of the commonest conditions under which reduction takes place are parasitism and the grouping of personæ into colonies.

A parasite is an animal living on or in the body of another, who is called its host. There are two conditions often confounded under the name—1st. Com-

* When several usually distinct forms are included in one species, each is called a sub-species; less distinct forms are varieties. As a rule, the groups poorest in species are the most aberrant.

mensalism, where one animal lives *on* and feeds *with* its host, but does not nourish itself at its expense. A commensal may be merely indebted to its host for house-room, as the Coronulæ on the Whale's skin (Oikosites), or it may feed on the food of its host, and then is a Koinosite. This is called pseudoparasitism. 2nd. A true parasite feeds on the tissues or juices of its host, and may be an ecto- or an endoparasite, according as it is attached to the outside or to the inside of its body surface.

In classification it is well to bear in mind that no character of structure or form is of equivalent taxonomic value in all tribes, but the value of each varies in each class (*Forbes*); also that a character is of good value in classification when its presence enables us to predict correlative but independent characters as accompanying it (*Rolleston*).

The origin of species is a favourite subject of theory, on which modern opinions may be ranged in two series—1st. The special creation hypothesis (whose advocates differ as to the number of separately created types, their opinions depending on their conceptions of species); and 2nd. The evolution theory, that different forms are descended from common stocks. The supporters of this view differ according as they attach a greater or lesser importance to the different physical causes of variation. The fact that scarcely two individuals are alike may be stated generally thus, that the descendants of a common stock are liable to vary. As a larger number of individuals are produced than can continue to exist under the conditions of food, temperature, and other surroundings, some only, and those necessarily the fittest, will survive; the fittest

being those whose variations of forms are correlated to their external conditions giving them the advantage over their congeners. The offspring of each individual usually inherit the parental peculiarities often intensified. Those that do not are (by hypothesis) at a disadvantage, and die off; hence permanent varieties, sub-species, and species arise. When we bear in mind that the physical conditions of nature in any place have been highly variable, it gives a greater force to this explanation of the method of variation.* This is *Mr. Darwin's* theory of Natural Selection. As a natural deduction from evolution, we have *Dr. Haughton's* law, that "all structures are arranged so as to give the maximum of work possible under the given external conditions," a law which is at the basis of the curious study of Dysteleology,† for by its operation it‡ cuts down all organs which, from altered external condi-

* But while explaining the method, Natural Selection does not explain the cause. In artificial selection the cause is the presidence and direction of human intellect. In Natural Selection there is a necessity for predicating the existence of a presidence similar in kind, but grander in degree, as the changes effected by it are greater than those that artificial selection can accomplish. This evolution theory explains the teleological correspondences noticed in animals, for by hypothesis the organ progresses according as the necessity for the function increases. Evolution also is morphological—that is, structures progress only along certain lines, and of this we can give no explanation, but can only say that it has been so—that is, evolution has progressed under law.

† Dysteleology is the study of rudimental and vanishing organs (*Haeckel*). They must be distinguished from provisional organs, which are structures useful in one period of life, disappearing in others. Rudiments may be constantly or only occasionally present in the species. They may be retrograded structures on account of parasitism, &c., or vanishing heirlooms of former lower states.

‡ I have here personified the law, as one must do in speaking of the operations of law in general, a significant fact, as it testifies to our consciousness that a law is nothing but the expression of a personal will.

tions, do not give the maximum of possible work, bringing them first to the condition of rudimental organs, and then causing their complete obsolescence.

CHAPTER VII.

DISTRIBUTION OF ANIMALS.

ANIMALS exist almost everywhere on the globe. Each form has a more or less extensive area. As a rule, synthetic and generalized types have the most limited ranges. Correlations in distribution are also noticeable, and hence the surface of the globe may be divided into provinces, each characterized by its own peculiar fauna. These provinces may be combined into larger tracts or regions, of which there are seven :—1st. Palæarctic, or the northern half of the Old World. 2nd. Nearctic, or America north of Mexico. 3rd. Neotropical, or Central, and South America (except Patagonia). 4th. Ethiopian, or Africa south of the Sahara. 5th. Indian and Malayan. 6th. Australian, or Australia and that part of the East Indian Archipelago south-east of the deep-sea boundary line pointed out by *Mr. Wallace.* 7th. Antarctica, or the region about the South Pole.

The provinces included here are as follows :—In the Palæarctic—1st. The Eastern Polar, characterised by the presence of the Reindeer, Lemming, Wolf, Arctic Fox, and many Mustelines, Salmonidæ, Auks, Divers, and Gulls ; and at its southern limit Grouse and Surnia, the land Molluscs, Limax, Arion, &c. 2nd. The Middle European, extending to the

Pyrenæo-Caucasian axial chain, characterised by the presence of many Bats, Red Deer and Roebuck, Dentirostral birds, many small Rodents, few true Reptiles, Cyprinoid fishes, Carabicine and Staphyline Beetles. 3rd. Aralo-Caspian, stretching to Siberia, rich in Rodents, Reptiles, the home of the Saiga Antelope. 4th. Tartarian, the plateau region of Asia, the home of the Horse, Sheep, Bactrian Camel, Yak, &c. 5th. Mediterranean, characterised by the Viverridæ, Jackal, Lion and Leopard, Fallow Deer, Pterocles, Flamingo, Ibis, Platalea, Pelican, and Coleoptera Heteromera. 6th. Japanese, the province of the Sieboldia, Inuus speciosus, Ursus lasiotis, &c. 7th. Chinese, the home of the Phasianidæ, Labyrinthobranch Fishes, &c.

In the Nearctic are included:—1st. The Western Circumpolar, resembling the Eastern closely, and characterised by the White Bear, Salmonidæ, Beaver, and fur animals, Musk Ox, &c. 2nd. North American, the region of the Insectivores, small Carnivores, Bison, Deer, Virginian Opossum, Dentirostral, and Conirostral Birds, Tortoises and Percoids, Unionidæ and Astacoids.

The Neotropical region includes:—1st. Mexico-Antillean, the home of the Ganoids, Amia, Lepidosteus, Scaphirhynchus, Phyllostomine Bats, Solenodon, Ascomys, Dicotyles, Cercolabes, Alligator, Anolius, land Crabs, and land Mollusca. 2nd. Brazilian, characterized by Edentates, Platyrrhine Monkeys, Vampires, Capybara, Pontoporia, and birds. This is the richest ornithological province in the world, the land of the Trochilidæ, &c. 3rd. Peruvian, the region of the Llama, Condor, Eriomys, Octodon, &c. 4. Pampas, the province of the Lagostomus, Harpalidæ, &c.

The Ethiopian includes:—1st. The Saharan, the home of the Ostrich, Hyæna, Jackal, Jerboa, Percnopterus, Varani, and Scincs, Locusts, and Melasomidæ. 2nd. The Guineean, the province of the Gorilla, Chimpanzee, Mandrill, Cercopithecus, Colobus, Manis and Orycterope, Hyæmoschus, Rhinoceros and Chœropsis, Manatees and Potamogale, Malapterurus, Polypterus, Gymnarchus, Termites, &c. 3rd. South African, the kingdom of the Antilopes, Pedetes, Giraffe, Lion, Hippopotamus, Gypogeranus, Snakes, the larger Cicindelidæ,

Achatinidæ, &c. 4th. Madagascar—according to *Haeckel*, a fragment of a once large central continent, Lemurien. Its fauna consists of Lemurs, Pteropine bats, Echinogale, Ericulus, Centetes; Didine birds and Æpyornis formerly lived herein. The Indo-Malayan region includes the following provinces:—1st. India, the home of the Tiger, Canidæ, Arctictis, Helictis, Paradoxurus, Catarrhine monkeys, especially Semnopithecus and Hylobates, Pteromys, Moschidæ, Platanista, Cinnyridæ, Bombycidæ, and Bdellidæ. 2nd. Malaya, the land of the Orang utan, Bats, Tarsius, Sumatran Rhinoceros, Tapir, Anoa, Babyroussa, Polyplectron, Peacocks, Argus Pheasants, Birds of Paradise, &c.

Australia includes two provinces:—1st. Polynesia, the kingdom of the Partulidæ, Nymphalidæ, Apteryx, Strigops, Nestor; and 2nd. Australia, the land of Marsupials and Monotremes, Bennett's Cassowary, the Emu, Menura, Scythrops, black Swan, Pezoporus, Scincs, &c.

The Antarctic region is little known. Patagonia, its first province, is characterised by the presence of the Guanaco, Dolichotus, Puma, and Rhea Darwinii. The other land regions in it are little known.

Marine animals are distributed in zones of different depths, of which five can be recognized:—1st. Superficial, the area of floating animals. 2nd. Littoral, or the region between tide marks, the home of Annelides, &c. 3. Laminarian, or that from low-water mark to about 10 fathoms. 4th. Intermediate or coralline, that from the level of about 10 fathoms to a varying depth from 40 to 60, or 100 fathoms. 5th. The Abyssal or deep sea zone, or that below 60-100 fathoms. Life in these zones is modified by currents hot or cold,* and varies geographically; thus, in the Arctic Ocean, the characteristic forms are the Walrus, Narwhal, Scorpæna, Salmonidæ, Amphipodous Crustacea, Chelyosoma, Cystingia, &c. In the Antarctic Ocean, are the Penguins and Auks, the

* Some animals can bear wide limits of change of temperature, and hence are called Eurythermal. Others are limited to regions where the temperature changes within very narrow limits; such are known as Stenothermal. Some forms can live in waters of very varying degrees of saltness, and are called Euryhaline (*Möbius*).

Falkland seals, &c. In the North Atlantic, Gadidæ and Clupæidæ, Porpoises and Dolphins, Rorquals and Whales, abound. In the Mediterranean, Labroids and Dolphins, Scomberoids, &c. In the North Pacific, Otaria, Enhydris, and Cataphracta. In the middle Atlantic, Plectognathi, Manatus, Petrels, Pteropods, and Cephalopoda. In the Indian Ocean, Buccinidæ, Dugongs, Hydroids, Tubipora, Rhinodon, Siluroids, Squamipinnes, Corals, and Echinodermata. In the Middle Pacific, are Corals and Holothurians in abundance. In the South Atlantic, the Proboscis Seal, the Cape Whale, &c. In the South Pacific, Physeter and Whales, also Polyzoa and Brachiopoda.*

Distribution in time, or Historical Zoology, is an important branch of Zoology, but one imperfectly known, owing to the impossibility of the preservation of soft parts in a fossil form. In the annexed table I have endeavoured to represent the order in which the various classes of the animal kingdom appear to have been developed, and their proportional importance in the life of each of the past periods of the world's history as far as is yet known. The study of extinct forms of life is called Palæontology.

* I am largely indebted to the works of *Schmarda* for this summary. (Die Geographische Verbreitung der Thiere, Wien, 1853; and Zoologie, 1871, Bd. 1, p. 111.)

TABLE OF THE DEVELOPMENT OF ANIMALS IN TIME.

Ages.	Rock thickness in miles.	Formations.	Protozoa.	Hydrozoa.	Actinozoa.	Echinodermata.	Vermes.	Bryozoa.	Brachiopoda.	Lamellibranch.	Cephalophora.	Cephalopoda.	Crustacea.	Insecta.	Arachnidæ.	Pisces.	Amphibia.	Reptilia.	Aves.	Mammalia.	Man.
Laurentian.	$5\frac{1}{2}$	Laurentian, . .	1	—	—	—	v?[6]	—	—	—	—	—	—	—	—	–	—	—	—	—	—
		Huronian, . .																			
		Cambrian, . .	v	v?[1]	—	v	v[7]	—	v	—	—	—	v	—	—	—	—	—	—	—	—
	8	Lower Silurian,	f	r[2]	v	m[4]	f	v	r	v	v	m[8]	r[10]	—	—	?[11]	—	—	—	—	—
		Upper Silurian,	—	r[3]	f	m[5]	f	f	x	f	f	m	r	—	—	v	—	—	—	—	—
		Devonian & Old Red Sandstone,	f	r[3]	f	m[5]	m	m	x	f	f	m	r	f	—	x	—	—	—	—	—
		Carboniferous Limestone and Coal measures,	f	r[3]	f	r[5]	m?	f	x	m	m	m	r	m	f	m	m	v?[12]	—	—	—
		Permian,	—	m	f	v	m?	f	r	m	m	m	m	m?	—?	m	m	f	—	—	—
Mesozoic.	2	Triassic, Lower, Middle, & Upr.	m	v	m	f	m?	m	m	m	m	r	m	m?	—?	m	r	r	f	f	—
		Lias, Oolite, Portland, & Purbeck = Jurassic,	r	f	r	r	m?	m	m	x	x	x[9]	m	r	f	r	m	x	f	f	—
		Chalk & Green Sand	x	f	r	x	m?	r	m	x	x	x	m	r??	?	r	m	x	m?	f?	—
Neozoic.	$1\frac{1}{4}$	Eocene, . . .	x	?	x	r	m?	r	mf	x	x	m	r	x	f?	r	m?	r?	r?	r	—
		Miocene, . . .	x	?	m	m	m?	m	f	x	x	f	m	r	f?	r?	m?	r?	r?	r	—
		Pliocene, . . .	x	?	x	r	x	x	f	x	x	f	m	x	f?	r?	m?	r?	r	r	?
		Pleistocene, . .	x	?	x	r	x	x	f	x	x	f	m	x	f?	r?	m?	r?	r	r	1
Quaternary		Living, ...	2700	750?	810?	800	4900	600	80	4380	15·600	230	3100	170·000	2000	13000	400	1500	8000	2300	1

x = very numerous in species and individuals.

r = numerous in species and individuals, m = moderate development specifically and individually, f = few species.

v = very few, and 1 = single species as yet known.

1. If Oldhamia be a Hydrozoan. 2. Graptolitidæ. 3. Mostly Rugosa. 4. Mostly Cystidea. 5. Mostly Crinoidea. 6. Scolithus-like burrows. 7. Histioderma, Arenicolites, known by their tracks. 8. Orthoceras, &c. 9 Ammonitidæ. 10. Trilobitidæ. 11. Conodontes, perhaps teeth of Marsipobranchs. 12. Eosaurus possibly was an Ichthyopterygian.

As the number of known species in extinct forms gives only a very imperfect idea of their absolute numbers existing, as the forms known are probably few in comparison with those unknown, so in the foregoing table I have not given numerical ratios or curves, as these are, with our present data, unreliable.

The total number of species known, as deduced from this list, is 233.250, but as many new species are described every year, this is a rapidly growing series. Several of the series are probably understated.

The animal kingdom includes eight sub-kingdoms, which may be grouped as follows into two series :—

1. Protozoa, having no definite body cavity = sub-kingdom I. Protozoa.
2. Metazoa, having a definite body cavity (Gastrula).

Sub-series—1. Polystomata, having many apertures into the body cavity = II. Porifera.

,, 2. Monostomata, having but one aperture of ingress into the cavity = III. Cœlenterata.

IV. Echinodermata.
V. Vermes.
VI. Mollusca.
VII. Arthropoda.
VIII. Vertebrata.

Of these the Cœlenterata and most of the Vermes agree in preserving their embryonic mouth as the true ingestive opening, and hence are called Archæosto-

mata, while in the Echinodermata, Chætognatha, and Enteropneusta, as well as in the higher sub-kingdoms, a second or adult mouth becomes substituted for the embryonic: these are called Deuterostomata. Possibly the Deuterostome worms should form a separate sub-kingdom, but I have refrained from dividing the great group Vermes until we have fuller information regarding some of its classes (Gephyrea, Rotatoria, and many of the aberrant forms).

The Deuterostomata differ primarily according to the nature of the body cavity, which may be formed:—1st. By outgrowths from the gastrula, as in Echinodermata, Chætognatha, and Enteropneusta (hence called Enterocœla). 2nd. By the splitting of the mesoblast, as in Molluscs and Polychæte Annelids, (hence called Schizocœla), or by an invagination of the epiblast, as in Tunicata and Amphioxus, (hence called Epicœla). Something like this method will doubtless be the classification of the future, but much embryological observation is yet required to correct and improve it.

CHAPTER VIII.

PROTOZOA (*Goldfuss*).

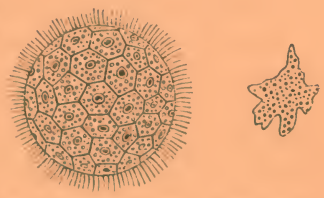
PLASTIDES, homo- or heteroplasts, generally minute; with no nervous system nor internal cavity; often forming shells or spicules, and containing, in their protoplasm, granules, usually a nucleus, often a nucleolus, and a clear contractile vesicle. They move by pseudopodia or cilia, rarely by a contractile layer.

This sub-kingdom includes eight classes, which form two diverging series.*

CLASS 1. MONERA (*Haeckel*).—The simplest living beings; organless, aquatic cytodes with pseudopodia; rounded when resting or starved, irregular otherwise; reproduction asexual.

There are two orders of these:—1st. Gymnomonera, with no resting stage nor capsule, reproducing by fission. They may be single, non-vacuolated with simple (Protamœba,† Fig. 1, A) or branched pseudopodia (Protogenes‡), or united in clusters by netted processes (Myxodictyon), or in vacuolated masses with irregular pseudopodia, found at great depths in the Atlantic Ocean (Bathybius§). 2nd. Lepomonera, with a resting stage in which the body becomes surrounded by a capsule, and the interior breaks up into flagellate spores, which on emission become like the parent. This includes Protomonas, a non-vacuolated form found in decaying Nitella stems; Protomyxa, marine, in its resting stage a round orange ball, whose contents break up into tailed spores, becoming vacuolated amœboid cytodes with branched pseudopodia; two or three of these coalesce to form a mass like the parent.‖ Vampyrella is non-vacuolated, and reproduces by tetraplasts, round masses at first dividing into two, then into four, &c. Each of these becomes rounded with radiating processes: they are parasitic on Algæ (three freshwater and one marine

Fig. 1.



Magosphæra planula. Protamœba. primitiva.

* Monera, Rhizopoda, Heliozoa lead us through Radiolaria to Porifera; Flagellata, through Peridiniæa and Infusoria, lead us to Turbellaria.

† Two marine and three freshwater species.

‡ One marine species.

§ Doubtful.

‖ This form may be propagated by artificial division.

species). Myxastrum, also non-vacuolated, marine, multiplies by germs produced by radial fission, each being enclosed in a siliceous envelope.

CLASS 2. LABYRINTHULEÆ (*Cienkowsky*).—Nucleated plastides found incrusting marine Algae, consisting of a central granular mass, sending off branching and interlacing fine protoplasm threads, possibly with a differentiated axis, and forming variable meshes with curved outlines. Through these threads, yellow spindle-like cells glide in different directions, and accumulate at certain parts of the thread in clusters. A non-nucleated freshwater form has recently been discovered on Sphagnum in Ireland by *Mr. Archer* (Chlamydomyxa).* These myxomycetoid forms require further examination. Reproduction takes place by fission; encystation of the spindles sometimes occurs.

CLASS 3. RHIZOPODA (*Dujardin*). — Indistinctly nucleated plastides, moving by filiform anastomosing pseudopodia, containing circulating granules, vacuoles, rarely one or more contractile vesicles. The yellow or brown protoplasm secretes, near the surface of its mass, a shell with one or many perforations, through which the pseudopodia project, and they generally form an expansion enclosing the shell. The shell is usually calcareous,† but may be siliceous (Polymorphina, Nonionina), or of agglutinated sand-grains (Textularia, &c.), or chitinous (Gromia), or scarcely

* Perhaps Pelomyxa (*Greef*) is related to these.

† $CaCO_3$ with Ca_2HPO_4 in Orbiculina adunca, &c. Siliceous spicules have been found in the spicules of Calcarina, Carpenteria, and around the mouth in the sessile conical Squamulina.

perceptible except by limiting the pseudopodia to one spot of origin (Lieberkühnia).

Its texture may be porcellanous (white, opaque), with a terminal opening, or vitreous and pierced by holes scattered over the surface. In the former case, pseudopodia project at the terminal opening; in the latter, they protrude over the whole surface. The shells may be one-celled oval (Ovulina), spiral (Cornuspira), or flask-like (Lagena), or many-celled, produced by continuous budding, but the whole mass makes up one persona (*Haeckel*). These chambers may succeed each other in a straight line* or in alternate series on two or three alternate axes, either forming a spiral† or not‡; or they may be successive, forming a spiral which may be discoidal§ or inequilateral‖; or the chambers may be wound on an axis, each embracing half its circumference¶; or, lastly, they may be in complete circles with a porous circumference,** or else irregular.†† The terminal opening may be round (Cornuspira), oval (Guttulina), crescentic (Spirulina), semicircular (Globigerina, Fig. 2), reniform (Triloculina), linear (Fusulina), or it may consist of several series of pores (Polystomella).

Each chamber may have a complete wall, or may be closed by the wall of its neighbouring compartment. They communicate by single or multiple pores, and each chamber may also have radial interseptal canals traversing the septa to the outer edge. The chambers, in some, form concentric rings around a central cell (the nucleus), each whorl being a continuous tube of which the chambers are regularly serial dilatations with narrow interspaces. The chambers

* Stichostegia, *D'Orbigny*.
† Entomostegia, *D'O*.
‡ Enallostegia.
§ Helicostegia Nautiloidea.
‖ H. Turbinoidea.
¶ Agathistegia.
** Cyclostegia.
†† Soroidea, *Schultze*.

are alternate in successive whorls, and from each chamber a tube passes inward to the narrow intercameral part of the whorl within (small Orbitolites). In larger forms of this genus, each whorl canal is horizontally divided into two parallel canals joined by many vertical branches, and the chambers are divided and displaced towards the surface, so that each communicates with its canal by a double passage. In the cycloidal Nummulites, each whorl not only surrounds the margin of the one within it, but invests its surface, thus producing rings of new chambers round the margin, while the superposed laminæ, lying close together on the surface, are separated by fine interlamellar spaces. There is thus a layer over the central cell for each cell between it and the margin. Each chamber communicates with its neighbours of the same whorl by several openings, and with those inside and outside by large diverging canals. Through each lamina pass fine parallel canals, except where the laminæ are joined by imperforate radial pillars. In these the sarcode is moulded to the cells, sends stolons through the canals, and pseudopodia through the marginal openings.

Living forms range from 0.3″ to 0.002″. Some fossil forms are much larger, several inches in diameter. Some sessile irregular forms also reach large sizes. Thus, Carpenteria consists of lobed conical masses, ceasing early to grow spirally, and attached to shells, &c.; dense sarcode protrudes through the apical opening with siliceous spicules (?). Polytrema is a scaly red encrustation on shells, &c., with no spicules. The oldest known fossil, Eozoon, from the Laurentian Serpentines of Canada, resembled these in

habit.* Shell growth is slow, but injuries can be repaired. Monstrous forms are not uncommon.†

Over 2,600 forms are known, living and fossil, and of these at least ten have survived from the Cretaceous period. They occur in the seas of all climates, but are most abundant in the superficial, littoral, and laminarian zones of tropical seas. When they die they sink to the bottom, and hence their dead shells are found at great depths.

Reproduction occurs by the formation of gemmules either with or without encystation (Truncatulina). In Miliola, granular, possibly reproductive, bodies have been seen, and Rotalian shells have been found filled with black spherules.

Two orders are included:—1. Imperforata, forms with chitinous, arenaceous, or porcellanous shells, having only the terminal aperture; of these there are five families.

1st. Gromidæ, test membranous one-celled, mouth simple, pseudopodia hyaline, the shell may be ovoid (Gromia‡), retort-shaped (Lagynis), or globular with a wedge-shaped neck (Sphenoderia), or the test may be scarcely detectible (Lieberkühnia). 2nd. Lituolidæ, shell arenaceous, often coarsely grained (Astrorhiza, Lituola), or smooth, fine-grained (Trochammina.) Valvulina is intermediate, with a perforate, vitreous, basal lamina, covered by the sand grains. The giant fossils, Parkeria and Loftusia,§ are related here. 3rd. Cornuspiridæ, calcareous, one-celled, discoidal, coiled shells, ex. Cornuspira. 4th. Miliolidæ, many-chambered, porcellanous; opening simple; whorls in one or several planes, sometimes irregular, sessile, adherent (Squamulina, Nubecularia‖), or large, bottle-shaped (Dactylopora,¶ Conodictyum), or discoidal (Orbiculina**), often Agathistegous (Miliola).

* Eozoon reached a large size, and was sessile, with numerous radial canals, and a distinct proper chamber wall. Many other Foraminifera make up rock masses. Fusulina, Miliola, and Globigerina are rock-forming materials in the Carboniferous, Eocene, and Cretaceous series, respectively.

† Dichotomous Nodosariæ, double Polystomellæ, &c.

‡ Freshwater.

§ Sometimes made the type of a family Parkeriadæ.

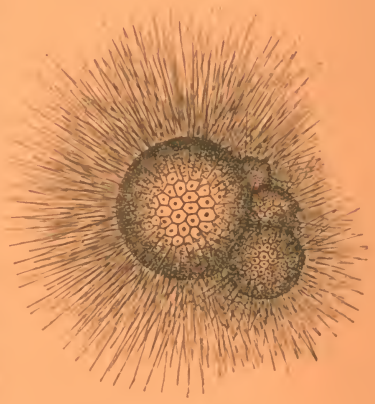
‖ Sometimes regarded as a separate family Nubeculariadæ.

¶ Similarly separated as Dactyloporidæ. ** Separated as Orbiculinidæ.

5th. Peneroplidæ, shells striated, brown, sometimes perforate, with single, lobulate, or branched openings; shells helicoid, ear-shaped, or discoidal, ex. Dendritina.

Order 2nd. Perforata or Foraminifera proper (*D'Orbigny*), shells vitreous, perforated, includes the following families:—1st. Lagenidæ—monothalamous; mouth circular; shell hard, finely perforated, ex. Lagena. 2nd. Orbulinidæ—monothalamous, with globose test. 3rd. Orthocerinidæ—chambers successive, in a straight (Nodosaria) or bent line (Dentalina), openings circular in the centre of the septum. 4th. Polymorphinidæ—cells alternating; sides unsymmetrical, sometimes with a bifurcating axis, ex. Bulimina.* 5th. Cristellaridæ—nautiloid, finely perforate; chambers encircling each other, with an opening at the upper angle, ex. Cristellaria. 6th. Nonioninidæ—vitreous, often siliceous; intercameral opening at the lower angle, ex. Eozoon, Siderolithes, Nonionina. 7th. Uvellinidæ—chambers uniserial, spiral, turbinate, coarsely perforate, ex. Globigerina, spinose when recent, Uvellina. 8th. Rotalinidæ—helicoid or turbinated, with embracing chambers, ex. Rosalina, Rotalia. 9th. Borelidæ—shell coiled on an elongated axis, divided by incomplete septa, ex. Borelis. 10th. Soritidæ—discoidal, with cycloidal whorls of chambers, ex. Cyclolina. 11th. Conulinidæ—axis straight, mouth of many pores, ex. Conulina. 12th. Textularidæ — axis elongated, chambers symmetrical, alternate, double rowed, (Frondicularia, Textularia). 13th. Cassidulinidæ—resembling the last, but with the axis once curved perpendicular to

Fig. 2.



Globigerina bulloides.

* Made the type of a family Buliminidæ.

the primary spiral. 14th. Nummulitidæ—finely perforate, with a special septal plane differentiated from the rest of the shell, without the ordinary tubular structure. Each chamber wall is complete in itself, ex. Archæodiscus, Polystomella,* Nummulites, Orbitoides, Fusulina?

Probably these are not true families, as outward characters are variable, and passage forms are numerous.†

CLASS 4. FLAGELLATA (*Ehrenberg*).—Nucleated plastides, each moving by a long, permanent, whip-like process; reproducing by fission or gemmation; motion is by swimming or rolling (Doxococcus).

They are divisible into two orders:—1st. Monadina—minute, vacuolated forms, with no differentiated ectosarc, and simple flagella. These comprise two families:—1st. Monadidæ—having a constant shape; reproducing by longitudinal or transverse fission; with one flagellum (Monas), or two (Glenomorum); sometimes with a red speck (Microglena); some are pear-shaped with a thick tail (Bodo), or the monads may be in clusters, each with two flagella (Uvella). In Anthophysa they are stalked, and have a contractile vesicle, and in Polytoma the clusters of monadiform spheres produced by incomplete division are within a hyaline cuticle. There may be an oval (Cryptomonas) or a flask-like lorica (Lagenella). Trichomonas has a few cilia as well as two flagella.

Fam. 2nd. Astasiidæ, with no lorica and a variable shape. Colacium is parasitic on crustaceans; others are free, with no red speck (Astasia), or with one (Euglena) or two (Diselmis). Peranema is rounded, tapering to the flagellum, with colourless granules and vacuoles within a thin cell-wall. There may be several (Polyselmis), or two equal (Zygoselmis) or

* Sometimes separated as a family Polystomellidæ.

† *D'Orbigny's* classification is embodied in a note on a former page: it takes for its basis the modes of budding. *Schultze* divided them on the same ground into Soroidea, Rhabdoidea, and Helicoidea.

unequal flagella (Heteronema*). Dinobryon has a loose lorica, and reproduces by continuous gemmation; hence it appears as a branched colony, each plastide of which has a pigment speck (absent in Epipyxis).†

Order 2nd. Noctilucæ—transparent, phosphorescent, globose, metabolic animals, about $\frac{1}{80}''$-$\frac{1}{40}''$. The body has a wide depression on one side (atrium), and a flagellum, consisting of a clear cuticle over a closely-transversely-striated axis, arising from a distinct papilla at its base; near its root at the bottom of the atrium is the mouth, opening into a short œsophagus. On the inner wall of the tube is a ridge, and from its floor springs a long cilium, near which are two brittle rods. The œsophagus ends in a mass of protoplasm, from which numbers of pseudopodia-like threads stretch in a netted manner like a skeleton, to the surface, getting finer as they approach it; along these threads vacuoles travel from the œsophagus. Outside these threads lies an ectosarc not divided into separate cell areas, but containing regularly disposed nuclei. Reproduction is by fission,‡ gemmation,§ or by conjugation and encystation, two individuals having approximated their mouths, their bodies become encysted. Another method is by the formation of swarm-spores (*Cienkowsky*), the protoplasm mass segments into 2, 4, 8, &c. On the ectosarc (which becomes saccular) arise surface tubercles, which form a disc or boss, each of these becomes zoospore-like, and moves about by its vibraculum.

CLASS 5. PROTOPLASTA‖ (*Haeckel*).—Nucleated plastides, having the central granule-, and vacuole-bearing protoplasm (endosarc) surrounded by a firmer differentiated layer (ectosarc), and often by a cuticle, so that the blunt lobose pseudopodia cannot coalesce when they come in contact (except in Actinophrys).

* The tail of the ametabolic Phacus is not to be confounded with a second flagellum.

† Some of these are probably vegetable.

‡ *Baddeley.* § *Gosse, Busch.*

‖ Lobosa, *Carpenter.*

Three orders are included:—1st. Catallacta (*Haeckel*)—marine forms, intermediate between Protoplasta and Flagellata; whose life-history consists of six stages: first, as a single, quiescent, globular plastide, which becomes multicellular, appearing as a spherical body filled with pear-shaped cells, each of which, at first stationary, begins to oscillate, becomes ciliated and free by bursting the parent cell-wall. It then assumes a peritricha-like form; its cilia thicken, coalesce, and become transformed into pseudopodia, the plastides becoming amœboid. To this order belongs Magosphaera planula (Fig. 1, A), from the North Sea. Possibly Syncrypta, Uroglena, and Synura (Uvella-like forms) may be spore stages of allied freshwater forms, with one flagellum, as *Archer* has noticed an amœboid stage in a Syncrypta-like form. Some suppose these to be modified Sponges.

Order 2. Amœbina—mostly freshwater, small,* with one or more wall-less contractile vesicles, and sometimes a structureless cuticle (*Auerbach*). Food enters by invagination, and in some the effete matters are expelled only at a limited area (villous region). They multiply by fission, gemmation (the throwing off of a pseudopodium), or encystation (the body becoming quiet, globular, slime-coated, losing its nucleus and contractile vesicle; then the endosarc divides into spherules, which traverse the ectosarc and become free, amœbiform). Arcellæ and Difflugiæ have been seen conjugating by *Cohn*.† *Carter* saw two amœbæ united (either conjugation or incomplete gemmation, *Schneider*). Difflugiæ and Arcellæ‡ have been seen dividing within their tests into resting spores (*Schneider*, *Perty*). *Carter* has seen the nucleus in Amœbæ and Euglyphæ becoming granular, and supposes it to be connected with a sexual form of reproduction.§ There are three families:—1st. Amœbidæ, with no hard test, shape constantly changing, owing to their inconstant pseudopodia,

* $\frac{1}{24}'' - \frac{1}{2500}''$.

† In some cases, the individuals conjugating were of different sizes and colours.

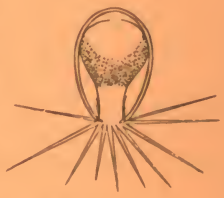
‡ *Schultze* saw the same in the Rhizopod Gromia.

§ As some higher animals pass through amœbiform states, some believe all these to be larval forms.

which are protruded at all sides (Amœba), or at one side only (A.limax), or radiating from one end (Petalopus). There may be a delicate test, but not sufficient to prevent the alterations in shape, incompletely (Pseudochlamys) or completely enclosing the body (Corycia), or a hyaline coat penetrable by the pseudopodia, after the retraction of which the openings disappear (Amphizonella). In Pamphagus, lobose pseudopodia protrude at one end, while in Diplophrys they are as tufts at each end. Boderia is a giant Amœba, reproducing somewhat as Magosphæra by pseudo-navicellar, but non-ciliated, bodies (*T. S. Wright*). Podostoma has flagelliform pseudopodia.

Fam. 2. Arcellidæ—(Fig. 3). Test firm, one-celled, it may be ovoid, coated with fine agglutinated sand-grains (Difflugia), with a down-directed mouth, or hyaline, flattened, facetted, often striated siliceous (?), with branched pseudopodia, and many contractile vesicles (Arcella). Euglypha has a regularly sculptured chitinoid test with depressions. Cyphoderia is spinose. Amphitrema has an opening at each end from which pseudopodia project. Echinopyxis sends its pseudopodia through short tubular processes of its test.

Fig. 3.



Platoum Parvum.

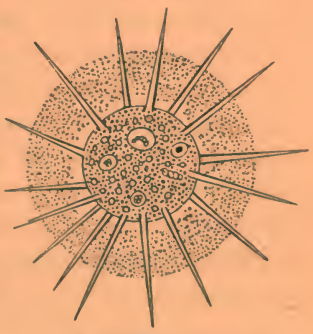
Fam. 3. Actinophryidæ—Minute, spheroidal, freshwater, slow-moving animals, with constant, radiant, ectosarcal pseudopodia, which often unite at their tips. The contractile vesicle is near the surface, and when distended appears as a bubble. The ectosarc is marked by polygonal meshes of granular protoplasmic threads enclosing vacuoles. They multiply by fission. The globular forms are named Actinophrys, if stalked, Podophrya,* if depressed with marginal pseudopodia, Trichodiscus. Clathrulina has a globular† stalked shell of lattice-work, through whose holes the pseudopodia protrude.

* If the pedicle be branched, Dendrosoma.

† Siliceous, *Greef*.

Order 3. Heliozoa—(Fig. 4). Protoplasta with radiant pseudopodia, often confounded with the last, but having a differentiated endosarc containing nucleated masses, and a vacuolated ectosarc, which appears alveolated. Each pseudopodium is compound, having a firm endosarcal axis and a hyaline granule-bearing ectosarcal surface-layer.* The endosarc has no central capsule. They multiply by division, natural or artificial, also (in Actinosphærium) by encystation and the division into many (10) resting spores, each in an Arcella-like siliceous hexagonal test. Raphidiophrys has fine siliceous spicules traversing the large green spherules, which make up the body. Acanthocystis is rounded with movable, straight, bifid, hollow spines, discoidal at the base, and curved flexible spicules.† Actinosphærium is globular, like Actinophrys in shape. Cystophrys has an irregular body, and many spherical endosarcal nucleated cells like the yellow cells of Radiolaria. Heterophrys is globular, with no spicules, and unbranched pseudopodia, but with central cells. Diaphoropodon has a difflugia-like test of foreign bodies. These are mostly freshwater forms, and many have recently been discovered by *Archer*, *Greef*, and *Focke*.

Fig. 4.



Heliosphæra radiata Sch.

* In feeding, these do not surround the food, but draw it into the ectosarc.

† It is often the nidus of a Rotatorian.

CHAPTER IX.

RADIOLARIA, &c.

CLASS 6. RADIOLARIA (*Müller*).—Heteroplastic personæ* or colonies,† with radiating, often anastomosing, pseudopodia. The endosarc is enclosed in a chitinoid central capsule,‡ pierced by fine pores, and consists of fine cells, pigment, fat spheres, crystals, and protoplasm, often with a median, sometimes compound, vesicle (*binnenblase* or *vesicula intima*) in its centre. The protoplasm varies from extreme fluidity (Collosphæridæ) to firmness (Acanthometridæ). The skeleton consists of spicules of silica or acanthin,§ lying outside, or radiating and piercing through the central capsule. They may be solid, clear, or striated (as in Dorataspis), or hollow, with a central canal traversed by a thread of protoplasm, which projects like a flagellum. The radiating spicules passing from the centre through the capsule are often joined regularly or irregularly by tangential beams, making up ornamental forms like discs, flower baskets, &c. The tangential beams may exist with no radiant spicules. Within the central capsule large nucleated cells sometimes exist, and concretions of leucin and tyrosin (*Kölliker*). In the ectosarc there are also cellular bodies and pigment spots; and a layer of large alveolar cells often surrounds the central capsule. Characteristic of the

* $\frac{1}{600}'' - \frac{1}{20}''$. † $\frac{1}{8}'' - \frac{1}{2}''$.

‡ Largest in Zygostephanus, smallest in Physematium.

§ Acanthin occurs in Acanthometridæ, is of cartilaginous consistence, destroyed by concentrated sulphuric acid. It seems to be the base in which silica is, sometimes at least, laid down, as some acanthin spicules silicify with age.

group are large yellow cells found imbedded in the sarcode, each included in a colourless membrane: these yellow cells are short-lived, and multiply by fission or endogenously. Their nuclei are sometimes red, and often resist the action of caustic alkali, as if encapsulated. Their number is variable, and not constant in any species; but they are rarely absent except in some Acanthometridæ. As they have been seen living and multiplying when the rest of the body was dead, *Cienkowsky* conjectured that they may be parasitic, but they are too constant to be so.

Radiolaria are found either floating on, or at the bottom of, the ocean, and they multiply by swarm-spores or germs, developed from the contents of the central capsule. *Müller* saw the inside of an Acanthometra full of monadiform vesicles, which became actinophrys-like. *Haeckel* noticed the capsule-contents of Sphærozoum breaking up into vesicles, and saw some of these vibrating. *Schneider* saw amœboid vesicles with movable flagella in Thalassicolla. The formation of these swarm-spores was minutely traced in Collosphæra (which has a fenestrated shell) by *Cienkowsky;* here the contents of the capsules break into little spheroids, which become monadiform, biciliated, and pass through the holes in the shell, each spore with a crystalline rod, and a few oil globules within. Young Radiolarians have no central capsule, thus showing their relations to Heliozoa. The shells of Radiolaria are abundant in some Tertiary deposits: those from Barbadoes earth are well-known as Polycystina. They existed as far back as the days of the Carboniferous formation, if the genus Traquairia be a true Radiolarian.

Radiolaria are divided into two orders :—1st. Monocyttaria, including the forms with a single central capsule. This includes sixteen families, grouped into three series according as they are devoid of spicules (Nuda), or possess spicules in the ectosarc (Ectolitha), or traversing the central capsule (Entolitha). There is one nude family:—1. Thalassicollidæ, with a globular, double contoured, central capsule, often marked polygonally on its surface, including Thalassicolla. Thalassolampe has no alveoli round the central capsule. Of Ectolitha there are seven families:—2. Myxobrachidæ, including large, soft, floating forms, with one or many contractile processes; the vesicula intima is constricted radially into a number of oval bladders. At the ends of the processes are *calcareous* concretions, either separate oval, lenticular, or oat-shaped (Coccoliths), or in clusters (Coccospheres). The yellow cells contain starch. These calcareous masses, and others cup-shaped (Cyatholiths) or rod-like (Rhabdoliths), are found in myriads imbedded in Bathybius, and in the mud of the Atlantic bottom, but nowhere else have they been found organically united to a definite body than in the arms of Myxobrachia (*Haeckel*).

3. Thalassosphæridæ, with tangential or radial skeleton of ununited, solid (Physematium, &c.), or hollow (Thalassoplaneta) spicules around the central capsule. 4. Aulacanthidæ, with hollow spines, partly tangential, partly radial, serrated, and loosely united. 5. Acanthodesmiadæ, with few, loosely united, sometimes ribbon or buckle-like spines. 6. Cystidæ, with the tangential skeleton forming conical or cup-like forms, with only one pole closed, and the central capsule at that end; there may be no mesial constriction (Litharachnium, &c.), or a longitudinal narrowing, dividing the body into lateral chambers (Petalospyris, &c.), or a transverse constriction (Lithomelissa) or several transverse constrictions (Eucyrtidium), or several both transverse and longitudinal (Botryocampe, &c.), The central capsule is often 4-lobed (Eucecryphalus, &c.) 7. Ethmosphæridæ, with a globular, basket-like skeleton, with radiating bars not piercing the central capsule (Heliosphæra). There may be two concentric spheres (Diplosphæra), or more (Arachnosphæra). 8. Aulosphæridæ, with hollow, tangential

spicules, loosely connected into a capsule, from which radiating spicules pass, with whorls of spines along their length. The meshes of the capsule are three-angled, and the double-contoured central capsule is freely movable within.

The Entolitha include eight families:—9. Cladococcidæ, forming a basket of solid radiant spicules. 10. Colodendridæ, similar, with hollow spicules. 11. Acanthometridæ, with no framework round the central capsule, but twenty radiant, symmetrical, acanthin spicules piercing it, either fused together in the middle (Astrolithinæ) or with wedge-shaped ends lying symmetrically beside each other (Acanthometrinæ), or only traversing the capsule, and not united at the centre (Acanthochiasminæ). The spicules are irregular in Litholophinæ; some have no yellow cells. 12. Diploconidæ, capsule not basket-shaped, open at both ends, narrow in the middle (dice-box shaped), with a strong-pointed spicule traversing the central capsule. 13. Ommatidæ, with a globular framework bound together by radiating spicules piercing the capsule. There may be one such frame and twenty rays (Dorataspis), two (Haliomma), or more (Actinomma). 14. Sponguridæ—The ento-capsular skeleton is spongy, and to this a system of radial spicules and an inner regular basket-work is often added. There may be, within, one or more of these lattice spheres, and an outer, irregular, sponge-like skeleton (Spongosphærinæ), sometimes as many as three of these spheres, as in Spongodictyum, or there may be no inner lattice sphere and irregular compartments in the outer sponge mass (Spongodiscinæ), or concentric inner chambers and no lattice sphere (Spongocyclinæ). 15. Discidæ, skeleton discoid or lenticular, with one or more concentric trellis-spheres, including the central capsule (Coccodiscinæ), or with the central chamber not so included, and spiral or concentric, ringed cavities in the skeleton (Discospirinæ). 16. Lithelidæ, skeleton of several discs whose compartments are arranged spirally on a common axis.

Order 2. Polycyttaria—Colonies; several central capsules in a common sarcode. This order includes two families:—1st. Sphærozoïdæ, having the central capsules included in a

common stock of vacuolated protoplasm, with no skeleton (Collozoum), or a few needle-like, tangential spicules (Sphærozoum). Raphidozoum has four-rayed, differentiated spicules. 2nd. Collosphæridæ, each central capsule supplied with a perforated sphere whose openings are simple (Collosphæra) or tubular (Siphonosphæra).

CLASS 7. GREGARININA.—Mostly parasitic, therefore degraded, forms,* one- or spuriously two-celled,† with a distinct imperforate cuticle, on which may be striae, knobs, ciliiform threads (Monocystis agilis), hooks or spines. They have no pseudopodia, but the ectosarc shows undulatory contractions from behind forwards. There is always a nucleus, often fat particles in the endosarc, but no contractile vesicle.‡ Sometimes there is a differentiated sub-cuticular layer of transverse moniliform fibres (in G. gigantea of the Lobster§). Food enters by endosmose or by invagination. Reproduction is by encystation, sometimes preceded by conjugation.‖ In the one-celled forms, the body becomes globular, the nucleus vanishes, and the contents form roundish, lanceolate bodies (pseudonavicellæ), which become free, and each bursting emits an active amœboid plastide, which by degrees becomes developed into a Gregarine (*Lieberkühn*). In G. gigantea, the amœboid bodies are first gymnocytodes, which become quiescent and spheroidal; then a tail-like process projects, or sometimes two, which

* A few free in decaying timber (*Hübner*).

† The cuticle does not dip in between the cells, but the septum consists of ectosarc alone.

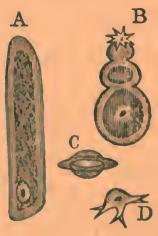
‡ In Dicystidean forms, the nucleus is in one compartment alone, the posterior.

§ *Lankester* regards this as only thickened cuticle.

‖ In G. longissima three have been found united.

are close together: one slender, shorter, and immovable; the other, stouter and movable. The latter becomes detached, and looks like a nematode, and the rest of the body also elongates into a worm-like form. (These pseudo-filariæ have, perhaps, been taken for nematodes by *Bruch* and *Leydig*.) Both these worms dilate at one end, and narrow at the other; their movements slacken, a nucleus and nucleolus appear, and an outer membrane forms: thus they become perfect Gregarines.

Fig. 5.



A. Monocystis lumbrici.
B. Pixinia rubecula.
C. Pseudonavicella of Zygocystis sp.
D. Amœbiform stage.

They are found in the intestines of Invertebrates, chiefly Arthropods, rarely in Vertebrates. Allied forms called Psorospermia may be stages of unknown Gregarines, and consist of spindle or pear-shaped cells, often tailed, with clear rounded bodies at their smaller end, and a protoplasm mass which sometimes is emitted as an amœbiform body. They occur abundantly in the muscles, &c., of Fishes and other Vertebrates.

Two families exist:—1. Monocystidea (*Stein*), with one compartment and a central nucleus; including Monocystis, found in worms (Fig. 5, A), the valves of the human heart, human kidney, pine-wood, beetles, Eunice, Nemerteans, &c. 2. Dicystidea, having two compartments, with a septal layer of ectosarc between, and the nucleus in the posterior; including Stylorhynchus, with hooks round the head, found in Calopteryx; Didymophyes, with three parts, head, fore, and hind body; Actinocephalus, with spines round the head; Gregarina, with no hooks, found in Ephemera Lobster, &c.; Pixinia, with hooks and a head separate from the front segment of the body (Fig. 5, B).

Leuckart and *Diesing* have shown that gregariniform bodies are developed from the eggs of Echinorhynchus Proteus (Gregarina miliaria and diffluens).

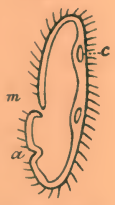
CHAPTER X.

INFUSORIA.

CLASS 8. INFUSORIA (*Wrisberg*).—Minute ($\frac{1}{2400}''$ – $\frac{1}{12}''$) ciliated bodies, probably simple plastides, or, at most, cytocormi, with a firm chitinous cuticle, an ectosarc and an endosarc, a contractile vesicle and a nucleus. A separate tubular fold of cuticle may form a sheath distinct from the outer body wall (Vaginicola), or the hinder end may be extended into a pedicle or an anchor apparatus (Trichodina). The cilia may cover the whole surface, and be all of the same kind (holotricha), or some may be long or specialized into styli, setæ, uncini (heterotricha). They may be on the under surface alone (hypotricha), or only on a peristome around the mouth (peritricha). Sometimes an undulating membrane takes the place of cilia (Undulina Pleuronema). The integument in Paramæcium, Nassula, Bursaria, &c., includes sharply contoured trichocysts like those of Turbellaria, considered as touch-organs by *Stein*, or as poison-organs by *Leuckart*. Beneath the cuticle in Stentor, Prorodon, &c., is a contractile, striped material, possibly a simple form of muscle. In Spirostomum these striæ are spiral, and the body contracts in their direction. The contractile stalk of Vorticella has also a highly-refracting muscular axis (*Kühne;* its muscularity is denied by *Mecznikow*, as it is structureless, myophanic). The outer layer of this stem is cuticle, and it straightens the stalk by its elasticity. There is usually a mouth, which may only be seen during feeding (Amphileptus, &c.), or it may have a ciliated pharynx (Paramæcium),

in which rod-like chitinous bodies—"teeth"—may exist (Nassula, Prorodon, &c.) There is usually an anus, which may be posterior, anterior, or in the vestibule of the mouth. The pharynx penetrates to the endosarc (or endoplasma), and terminates therein sometimes with a valve (Glaucoma); the food there passes round in the protoplasm, often in vacuoles, and is digested. The ectosarc (ectoplasma) is firmer, more homogeneous, and possesses a contractile vesicle at either or both ends. These contract rhythmically, often fifty times in a minute, and the fluid within is expelled into the parenchyma or out by surface-pores. One or many canals may be attached to this vesicle: (1, Spirostomum; 8.10, Paramæcium; 30, Bursaria). They appear to have definite walls, and are filled when the vesicle contracts, or *vice versa*. In Stentor there is a circular canal around the mouth connected with the vesicle. The contractions of these vesicles are independent of the circulatory movement of the protoplasmic endosarc, which is usually active, although the contained granules are not contractile.

Fig. 6.



Section of Paramæcium.
m. mouth.
c. contractile vesicle.
a. anus.

The body in Trachelius ovum (Fig. 7) consists of an endosarc of protoplasm threads, forming irregular meshes, whose interspaces are filled with water. These threads functionally represent the endosarc of other Infusorians, but remind us of Noctiluca. The ectosarc is thin, and its contractile vesicle is lenticular and flattened.

Fig. 7.

Section of Trachelius ovum.
a. mouth.

The only possible sense-organs

are the pigment spots in Ophryoglena, which may be photoscopic eyes, and consist of highly-refracting granules on the convexity of a clear, watch-glass-like body. The latter structure exists in Bursaria without pigment. Below the pharynx in Opercularia are two, reniform, solid organs of unknown nature. A solid body (nucleus) exists in all, sometimes movable, and generally oval, band-like (Bursaria, Trachelius), or string-like (Ophryoscolex), sometimes bent round the pharynx (Vorticella). Within or beside the nucleus is a rod-like nucleolus.

Reproduction is by longitudinal, transverse, or diagonal (Lagenophrys), fission, gemmation (Vorticella), encystation, internal gemmation (Loxodes bursaria, *Cohn*), or sexually by conjugation, often of unequal individuals (Paramæcium). The nucleus (ovary) splits into spheres, or ova; the nucleolus, into thread-like or rod-like spermatozoa. These become interchanged in the two conjugating individuals, and the ova develop. *Stein* describes having seen a brood-canal for the extrusion of the germs.

These animals abound in stagnant waters, infusions, &c. Some are parasitic, and a few marine, some of which are phosphorescent. They may be divided provisionally into four orders.

1. Opalinæa—oval, parasitic, sluggish, and mouthless; with a ligulate nucleus, no contractile vesicle, but several permanent saccular spaces, or a contractile canal in O. Planariarum and O. uncinata. They may be holotrichal, or the cilia on the under surface may become uncini (Alastor), or a wavy undulating membrane may replace the cilia (Undulina). A mouth-like depression, with a row of comb-like cilia, exists in Plagiotoma. They increase by transverse fission, are found in the intestines, &c., of Frogs, Newts, Molluscs, &c., and

may be, as *Agassiz* supposes, early stages of Trematode worms.

2. Peridiniæa—mouthless (mouth-bearing, *Schmarda*), free, loricated forms, with a transverse ciliated furrow, no contractile vesicle, but with a nucleus, vacuoles and chlorophyll granules. Some have a red pigment spot (Glenodinium); others have two or three long, curved, horn-like processes (Ceratium). The lorica is often double, chitinous (or siliceous?). Many are marine, and vividly phosphorescent; they multiply by longitudinal or transverse fission, and have been seen full of globules (*Perty*). *Bailey* regards some of these as Annelid-larvæ. They unite Flagellata and Infusoria.

3. Acinetina—stalked, membrane-clad forms with radiant, retractile, tubular processes, whereby nourishment is sucked in (hence called Suctoria by *Claparède*, and Polystoma by *Greene*). The stalk is an extension of the cuticle, and is sometimes striated. The processes may be branched (Dendrocometes),* or in bundles, especially when the body is lobate; sometimes only one suctorial arm may exist (Rhyncheta, parasitic on Cyclops). The endosarc contains granules, and a nucleus with apparently an investing membrane. The ectosarc includes one or more contractile vesicles. By the processes which the animal applies to its host, currents of food granules enter and coalesce within into food globules. They multiply by gemmation, rarely by fission. We know little of their life-cycle. Some are, perhaps, as *Stein* supposes, larval, but this is denied by *Claparède* and *Lachmann*. *Eberhard* saw one form becoming ciliated and changing into Bursaria truncatella. Ophryodendron is commensal with Plumularia, and has two classes of zooids, proboscidean and lageniform, both mounted on curved stalks.

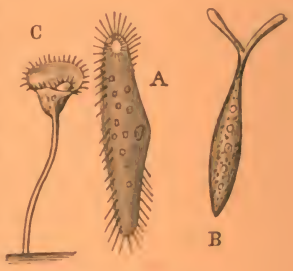
4. Stomatoda includes the mouth-bearing forms, and consists of four sub-orders:—1. Peritricha, with a ciliated peristome, including five families:—1. Vorticellidæ (Fig. 8, C)—stalked, bell-shaped forms, with mouth and anus opening inside the peristome. The stalk may abort and the bell be sessile (Scyphidia, Gerda), or it may be rigid, branched or un-

* The larva of Spirochona gemmipara (*Stein*).

branched, with (Spirochona) or without (Epistylis) a spiral leaf-like appendage to the peristome. The stalk is flexible, unbranched in Vorticella, and on irritation contracts suddenly into a close spiral. They multiply by longitudinal fission, one half, being freed from the stalk, developing a posterior crown of cilia, and a mouth at that side, while a new stalk grows at what before was the anterior end. Buds may form at the base of the bell, or encystation may take place, the nucleus splitting into monadiform bodies, each of which, becoming free, develops into an Acineta (*Stein*). Carchesium has a branched flexible stalk, but the muscle-band in each branch is independent. Zoothamnion has a branching muscle, as well as stalk, and some of the buds thereon remain permanently globular and unexpanded. Urocentrum has a pedicle, but is unattached.

2. Trichodinidæ—urn-like, with an anterior and posterior crown of cilia, peristome not capable of closure. Trichodina, parasitic on Hydra, has an anchor apparatus at the posterior end, consisting of a chitinous ring with two rows of recurved uncini, and a flexible, finely striated collar outside this and above its base. Halteria has two similar ciliary crowns, but no anchoring apparatus.

Fig. 8.



A. Oxytricha gibba.
B. Trachelocerca biceps.
C. Vorticella citrina.

3. Ophrydinidæ—often clustered, included in a sheath, seldom stalked. If the lorica be gelatinous, and by imperfect division hold together the perfectly divided animals, they form soft masses often over an inch in diameter (Ophrydium). In isolated forms the animal may be sessile in the lorica (Vaginicola), or stalked (Tintinnus), or the lorica itself may be rigidly stalked (Cothurnia).

4. Dictyocystidæ are marine forms with a siliceous, perorate, bell-shaped shell like that of a Radiolarian. Codonella is closely allied, with a bell-shaped perforate test and a double peristome; it is made the type of a separate family by *Haeckel*.

5. Ophryoscolecidæ—naked forms (found in the paunch of Ruminants) with an anterior crown of a few cilia.

Sub-order 2. Holotricha—uniformly ciliated, including seven families. 6. Cyclidinidæ—aproctous, body flat or oval, sometimes bristly, Cyclidium. 7. Enchelidæ—mouth and anus at opposite poles; pharynx with no teeth; body naked, oval (Enchelys), or with a long, narrow neck, and a laterally lipped mouth (Lacrymaria). Leucophrys is parasitic, with a wide neck and an ad-oral ciliary spiral. 8. Chilodontidæ have an oval, striated surface with rows of cilia, mouth tubular, anterior (Prorodon), or beneath, with lips and tooth-like processes. The teeth may be numerous, as a wheel-like circlet of hooks (Nassula), or with a lip-like anterior process (Chilodon). In these, living embryos arise by a process of encystation. Wagneria, whose mouth apparatus resembles that of Prorodon, has two distal ciliated zones like Trichodina. 9. Colepidæ—loricated, with mouth and anus at opposite poles; shell striated, perforated, toothed in front and behind. 10. Tracheliidæ—ciliated, shell-less, longitudinally striated, oval or irregular, with an antero-inferior mouth, no teeth, and a narrow anterior proboscis, with sometimes eyelid-like valves to the mouth (Glaucoma). Trachelius is mentioned before (p. 67, Fig. 7). 11. Ophryocercidæ—mouth anterior, anus ventral; the front end is sometimes bifid (Trachelocerca biceps, Fig. 8, B). 12. Colpodidæ—shell-less, mouth and anus ventral, sometimes with a tongue-like tuft of oral cilia (Colpoda, common in hay infusions), or with eye-specks (Ophryoglena). Amphileptus has no tongue-like process, and is narrowed fore and aft into a proboscis and tail. Uroleptus has only a tail. Paramæcium (Fig. 6), very common; has a compressed slipper-shaped body, a lateral mouth, and stellate contractile vesicles.

Sub-order 3. Heterotricha—possessing a second, longer set of cilia near the mouth, and fine cilia over the body. This includes two families. Bursaridæ, with the mouth at the bottom of a deep slit, not anterior, and guarded by long cilia. The anus is posterior; the peristome is not spiral. Bursaria is parasitic (in Man, Swine, Frogs). Spirostomum, the largest Infusorium, is flattened and elongate, with a

moniliform pulsating vesicle. 14. Stentoridæ—funnel-shaped, naked (Stentor), or surrounded by a gelatinous capsule, with a spiral peristome of long cilia, mouth and anus close in the same groove; nucleus moniliform; front of the body two-valved (Freia) or ribbon-like, spirally inrolled (Chætospira).

Sub-order 4. Hypotricha—only ciliated on one (the under) side; including four families. 15. Oxytrichidæ—possessing bristles (Oxytricha, Fig. 8, A), hooks (Kerona), or styles (Urostyla), or both hooks and styles (Stylonychia), by help of which they can walk; shell-less, or with very thin test and marginal cilia; one form (Kerona polyporum) is parasitic in Hydra. 16. Euplotidæ—with a distinct test, hooks and styles, ex. Euplotes. 17. Dysteridæ—with a tail-like foot, and a membranous carapace of two separate (Iduna), or united valves (Dysteria), or with no carapace (Huxleya). 18. Aspidiscidæ—shield-shaped, with a test; cilia reaching to the anterior edge; pharynx not obvious; locomotory process as in Euplotidæ, but with no fine cilia.

CHAPTER XI.

SUB-KINGDOM II.—POLYSTOMATA (*Huxley*).

AQUATIC animals, made up of differentiated plastides, bounding a central cavity, thus forming Gastrulæ. The cavity communicates with the external water by many pores or interstices between the cells of the wall, as well as by one or more terminal mouths or oscula formed by absorption at one point in the wall of the polyplast (*Haeckel*), or by invagination (in Sycon ciliatum, *Metschnikoff*). Sexual reproduction often occurs, but there are no highly specialized tissues.

There is one class included:—

CLASS 1. PORIFERA (*Grant*)—Sponges, whose characters are those of the sub-kingdom.

The plastides are, in simple Sponges, arranged in two layers, forming an outer (ectodermal) and an inner (endodermal) wall for the central cavity. They may be cytodes or cells, often amœboid and naked, or with a thin, rarely a thick, cell wall; some or all of them being ciliated or flagellate. In some forms the protoplasm is undifferentiated, with free nuclei. The interstitial pores often are inconstant, but may become branching varicose canals. The walls of the central cavity frequently become irregularly folded, and by coalescence of the several folds and dilatation of their communicating pores, the single central cavity becomes the focus from which irregular tubular branches pass; by lateral budding, new zooids form beside the older ones, and the branches from the central cavities of each, communicate with the irregular sinuous interzoöidal spaces, thus giving rise to the complicated system of passages found in such colonies as those of the common toilet Sponge. In some the pores enlarge into pseudoscula (Geodiinæ), or even into true oscula (*Miklucho-Maclay*).

Sometimes, as in Axinella, and less distinctly in Raphiophora, there is a regularly radiant system of canals from the osculum, foreshadowing the radial symmetry of Cœlenterates.

Through the surface pores currents of fluid enter the body cavity, propelled inwards by the cilia or flagella of the lining plastides,* and expelled through the large osculum or efferent aperture. The lining plastides are nourished by the organic particles in the

* These may be uniformly distributed, or else there may be here and there small cavities lined by ciliated cells, while the intervening passages possess only amœbiform plastides.

passing fluid, which they take in after the manner of Rhizopods, so that each plastide nourishes itself, as do the separate plastides of higher organisms. In rare cases (Guancha blanca), the osculum serves as a mouth, taking in, as well as ejecting, the water (*Miklucho-Maclay*). The pores may close, and the osculum diminish in size, by contraction of the surrounding plastides. The osculum may be simple, or may have a circlet of lobes or papillæ, forming a rudimental tentacular crown, as in Osculina. In some forms, true connective tissue is differentiated beneath the plastide layer in the lining of the central cavity, partly accompanying the canals and partly traversing the sarcode. In the intermarginal cavities of Geodia, fusiform contractile cells, identical with smooth muscle-cells, also exist.

The surface plastides of many are differentiated into a uni- or multi-lamellar epidermis, often continuous over a whole colony. This layer in Reniera* and Desmacella contains thread cells like those to be described in the next sub-kingdom (Fig. 10). Under this cuticle are often extensive sub-cuticular and intermarginal spaces, into which open surface pores from without, and the canals of the zooids from within.

The individuality of a Sponge has been a matter of dispute. *Carter* and *James-Clark* regard the "sarcoids" or separate plastides as morphological individuals; but the arguments in favour of this theory would equally apply to the separate endoplasts of a Cœlenterate, or to the white corpuscles of the human blood. The view of zooidal individuality stated above

* Cnidæ are also found around the spicules, and especially about the stomach, in Reniera (*Eimer*).

is the only one consistent with the varieties of structure presented in the class.

The plastides are usually supported on spicules of calcium carbonate, silica or horny matter (Spongiolin), which are formed by the deposition of the indurating material in a protoplasmic base. The mineral spicules are not crystalline, but laid down particle by particle, often in laminæ. They sometimes have a central cavity filled with an organic material (protoplasm ?*), for, when heated, they often burst at one end, and become blackened inside.

In size the spicules vary from $\frac{1}{50}''$ – $1'$ (Hyalonema). They are named from their shapes, and may be bi-, tri-, or hexradiate, according to the number of diverging rays; or, if quinque-radiate, may have long or short axes, and simple or forked rays. Some are simply acerate (needle-shaped), pin-shaped, club-shaped, fusiform, cylindrical, furcate, radiate, spinulate, rotulate (wheel-like), or birotulate (like two-toothed wheels joined by an axle), or sinuous. Some are hamate (hooked), or C- or S-shaped; others umbonate, anchor-like, candelabriform or spheroidal. These names are sufficiently expressive. The spicules are supposed to discharge different functions, and are grouped into:—1st. Skeletal or essential, supporting the body. 2. Connecting, retaining the outer layer (when it is differentiated) in connexion with the interior. 3. Prehensile—projecting as a means of attachment to other bodies. 4. Defensive—projecting externally to prevent their being preyed upon. 5. Spicules of the surface membrane, which may strengthen or support its plastides; these may be either (α) tension spicules to keep it stretched, or (β) retentive (hamate or anchorate), keeping it in its place.

Reproduction takes place:—1st. Sexually, by the differentiation of some of the deeper plastides, along the line of the larger canals, into ova; others are con-

* Candelabriform spicules are solid.

verted into mother-cells, whose nuclei become spermatozoa, and rupturing the cell wall these flagellate bodies are emitted, and fertilize the ova, which become, by segmentation, first morulæ, then ciliated germs, with a bilaminar membrane surrounding a central cavity (planulæ), whose pole becomes thinned and perforated by absorption (*Haeckel; Metschnikoff* describes the cavity in Sycon ciliatum as formed by invagination). Sexual reproduction has been detected in Tethya, Reniera, many Calcispongia, &c.

2nd. Asexual reproduction may occur by division, natural or artificial, or by budding, either continuously, thus forming colonies, or discontinuously, by the formation of detached gemmules. In the freshwater Spongilla these are either ciliated plastides or swarm-spores, or else rounded masses found in the older parts of the animal's body, consisting of a central cluster of soft cells surrounded by a globular coriaceous capsule pierced by an opening, and outside which is a crust containing radial, dentated birotulate spicules (Amphidiscs). These "winter eggs" grow in spring by processes protruded through the infundibulum, or opening.

Sponges are divisible into eight orders:—

Order 1. Halisarcia—a doubtful group, including soft, skeletonless forms, probably immature states of other Sponges.

Order 2. Ceraospongia—Sponges with a skeleton of Spongiolin fibres, 0.07 – 0.004 mm. in diameter, making an irregular horny net-work. These may be similar, homogeneous, structureless (when young), or consisting of concentric laminæ (Spongia, Ditela); or with a differentiated axis (Verongia, Aplysina); or an axis of sand grains and of the spicules of other Sponges (Dysidea): or of special spicules, either fully included (Chalina) or projecting on the surface (Clathria); or else some fibres may be coarse and with a

sandy axis, while others are fine, homogeneous (Hircinia). Auliskia has its fibres traversed by an Algoid? Cacospongia is loose in texture, with laminated, slightly elastic threads. Spongelia is hard, brittle, and scarcely elastic.

Order 3. Gumminæ—horny, caoutchouc-like Sponges composed of densely interwoven homogeneous or striated fibres, or of mucous tissue imbedding stellate spicules. In the basis are often cartilage-like cells (*Kölliker*). Spicules may be candelabriform (Corticium), or none (Gummina), or there may be an outer surface of compacted fibres and stellate spicules (Chondrilla).

Order 4. Halichondriæ—siliceous Sponges, with no cortical layer, and a small amount of Spongiolin, with no anchorate nor defensive spicules. They may be massive, with cylindrical needle-like spicules (Halichondriidæ); or rugose, with simple spicules usually pointed at both ends (Reniera); or blunt, often knobbed at the end (Suberites). Ancorina is fleshy, with acicular spicules. Clionidæ are mostly boring Sponges, with pin-shaped spicules, perforating oyster-shells, limestone, &c. They have often two kinds of papillæ, pore-bearing, small, and osculum-bearing, larger, fewer. The surface may be beset with siliceous polygonal plates (Cliona), or mulberry-like bodies (Thoosa). Raphiophora patera (Neptune's cup) is a large goblet-like Sponge, 2 – 4 feet in height, with numerous octoradiate oscula. Raphyrus is an allied, irregular form. The family Arenospongidæ, including the genus Xenospongia, which forms a disc of agglutinated sand, and possesses diverging spicules in the sarcode and around the oscula, may be worthy of ordinal rank.

Order 5. Corticatæ—globose, tuberous or branched, with an outer cortex containing spiculigerous corpuscles, and an inner layer of Spongiolin threads and siliceous needles, often in radiating sheaves. Sometimes the cortex is thin, membranous (Tisiphonia), or thicker, provided with siliceous globules and needles (Geodia), or globules only (Caminus). Pachymatisma has short fascicles of spicules, and an unsymmetrical central mass. Tethya is massive, sub-orbicular, with a skeleton of fasciculate spicules radiating to the surface, with sub-cuticular unsymmetrical cavities. The cortical spicules

are uniform, simple, with stellules. Steletta has both simple and anchorate spicules. The central spicules in Geodia are grouped in long, radiating fascicles. Placospongia is branched like a coral, with a central axis separated from the cortex by a sarcode layer.

Order 6. Acanthospongia—including the Hexactinellæ of *Schmidt;* siliceous Sponges with hooked, anchorate, triradiate, or stellate spicules, separate or soldered into a continuous network. The sarcode is soft, and contains little differentiated matter. Euplectella, the beautiful "Venus' flower basket" of the Philippines, has the upper end of its tubular cavity closed with a flinty network. Hyalonema has a long twisted "glass rope" of spicules around the elongated osculum (cloaca). Esperia has spindle-shaped or linear needles, with hooks, anchors, &c., in the membrane or sarcode; the personæ in some Esperiæ are polypoid and bilaminar. Dactylocalyx is massive, with the spicules ankylosed into a coral-like, expanded mass. Aphrocallistes is tubular, with a net-like, continuous skeleton of siliceous threads. Holtenia is a remarkable bearded form, dredged in the North Atlantic. Allied to this order is the group Lithistidæ, proposed by *Schmidt* for Sponges with a continuous skeleton, but without hex-radiate spicules.

Order 7. Potamospongia—massive or branched, often green,* freshwater Sponges, with siliceous spicules united by Spongiolin threads; the ova have a coriaceous, spiculigerous envelope. This includes the Spongillæ of our rivers (S. fluviatilis) or lakes (S. lacustris), which have smooth or echinulated (S. echinata) spicules.

Order 8. Calcispongia—mostly littoral, smooth, white Sponges, with calcareous, acicular, or triradiate spicules. They may be single personæ, with (Monosyca) or without a mouth (Clistosyca); or colonies with one (Cœnosyca) or many mouths (Polysyca); or a stock may have no mouth (Cophosyca). The body wall may be solid, or pierced by simple pores, or by regular or irregular canals. Many of them develop sexual products, the spermatozoa being the

* Containing Chlorophyll.

flagellate nuclei of modified endodermal (?) cells. The forms included herein are singularly plastic, easily modified by external conditions. The group with inconstant, simple, dermal pores constitutes the sub-order Ascones.* The series with tortuous branched canals in the wall of the gastræal cavity are named Leucones, while those with regular, straight, unbranched vessels and budding tubes are Sycones; any of these may possess either simple or three- or four-rayed spicules, or two or more kinds together, and by these *Haeckel* divides them into genera. The flagellate plastides of Leucosolenia (Ascones) have been regarded by *James-Clark* as separate organisms grouped in a colony (see Synura).

CHAPTER XII.

SUB-KINGDOM 3.—CŒLENTERATA† (*Leuckart*).

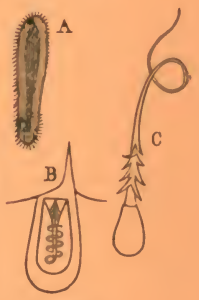
AQUATIC radiated personæ (often in colonies) of more than two antimeres, having a body cavity opening at one pole by a mouth often surrounded by feelers (tentacles). The body consists of two membranes, an inner, cellular or endoderm, which at the mouth joins the outer, or ectoderm. In the colonial forms, the tubular prolongation of the body cavity of each persona communicates with that of its neighbours in the common stem of the colony (Cœnosarc), allowing of community of nutrition, and the fluid, produced by digestion in the stomach of each, circulates in this tubular system, moved by the lining cilia. Differentiations of the ectoderm form support-, loco-

* These are the simplest known gastrulæ.

† Diploblastica (*Lankester*), called so in contrast with the Ablastica (Protozoa), and Triploblastica, including all the other Metazoa.

motory, and usually generative organs. The outer surface is rarely ciliated in the adult, except in Ctenophora. In the protoplasmic ectoderm exist scattered or clustered nettle-cells (cnidæ or trichocysts), (Fig. 9, B C), which are minute oval capsules filled with fluid, and consisting of a fine homogeneous outer layer, lined by a delicate membrane, which at the apex is involuted into an axial tube, ending in a long, coiled, barbed thread. The slightest contact ruptures the outer layer, the tube becomes everted, and from its summit the thread suddenly uncoils and becomes rigid. The everted tube is armed with three or more barbs (Fig. 9, C). A simpler form consists of a simple sac and filament with no tube; sometimes a second filament exists in an oblong saccule at the barbed end of the first thread. These are used in benumbing their prey by adhesion, penetration, and possibly by some virus; but each cell can only act once. In development, they first appear as clear particles, which soon assume a double contour (and sometimes exhibit amœboid motions); then the spiral thread appears within, and the cell becomes superficial and ready to act. They are most numerous on the tentacles, and often regularly arranged.

Fig. 9.



A. Planula.
B. Thread cell.
C. The same with the thread protruded

Sexual reproduction occurs in every species, and the term individual is applied to the total product of a single impregnated ovum: when this consists of parts which sustain separate existence, each part is called a zooid.

The group is divisible into two classes :—

CLASS 1. HYDROZOA—Saccular or tubular personæ, either single or in varying degrees of aggregation, with no separate digestive sac, and with the reproductive organs external. To each individual, whether persona or colony, the name Hydrosoma is given. The following sub-classes are here included :—

Sub-class 1. Hydroida—locomotion never by meridional rows of cilia; generative elements discharging themselves externally. The zooids serving for the nutrition of the hydrosoma are never joined in free swimming colonies with the reproductive zooids.

Four orders are included :—

1. Eleutheroblastea (*Allman*).—Hydras are separate personæ attached at will by an aboral disc, and consisting of a tubular digestive cavity with no anus. The 4-10* tubular tentacles are prolongations of both endo- and ecto-derm (Fig. 10 T), and vary in length from $\frac{1}{4}''$ to 10 times the length of the body (which is ·08″ – ·4″, or even more). The ectoderm consists of large nucleated cells, from whose bases filamentary processes are continued inwards (Fig. 11, A). *Kleinenberg* regards these as nerve cells, and the processes as muscular, thus forming the simplest differentiated neuro-muscular apparatus. Between these cells are smaller irregular interstitial cells, not forming a special layer, but surrounding the bases of the first series, and containing the nettle cells, which often appear sunk in the sides of the larger ectodermal cells.

Fig. 10.

Hydra aurantiaca. T, tentacles; *o*, ovary *sp.* spermigenous papilla.

* Rarely twelve or more.

Fine bristles (palpocils) project from the walls of some of the surface interstitial cells (seen on the thread cell in Fig. 9, B; protoplastic processes of *T. S. Wright*). The endoderm cells are large, unilaminar, vacuolated, often flagellate, often with no distinct cell wall. The thread-like processes of the ectoderm cells, united by a copious intercellular substance, form an intermediate layer of vertical fibres* (described by *Kölliker*). Amœboid cells wander through both layers. The tentacles are not transversely septate, and their ectoderm is rich in interstitial tissue, and contains both kinds of thread-cells and palpocils.

Fig. 11.

A. Neuro-muscular cell.
B. Spermatozoon of Hydra viridis.
C. Ovum of H. viridis.
D. Hydra viridis, showing the formation of buds.

Reproduction may be by fission, and if artificially cut up, all the lost parts are rapidly reproduced, and buds may spring from any part except the tentacles (Fig. 11, D), most frequently from the proximal end, or that nearest the aboral disc. Each bud contains a prolongation of the endoderm and ectoderm and a pouch of the body cavity; a mouth and one or two nodular tentacles develop at the distal end; the latter expand and increase in number; the body cavity at the base of the bud narrows, closes, and the bud falls off (in from three days to six months). Detachment may occur before the aboral cavity is perfectly closed, leaving the

* These fibres are more highly refracting when treated with acetic acid than the granular contents of the basis of the ectoderm cells.

minute anal opening described by *Corda*, *Leydig*, and *Hancock*. A second race of buds may form on the growing bud before its detachment: indeed, as many as five such progenies have been found united. This process is frequent in summer.

Sexual reproduction is commonest in autumn, but is not confined to any season. The spermigenous organs form near the base of the tentacles (Fig. 10, *sp.*) At one spot, the interstitial ectodermal cells enlarge, and become polyhedral, and with them are found amœboid cells. The neighbouring neuro-muscular cells thin out, and form a coating over this now conical or wart-like growth. The nuclei in the altered cells disappear, and their contents become granular and confluent. Then from the amœboid cells, oval refracting spermatozoa (Fig. 11, B) form, and become flagellate, and escape into the surrounding water through an apical opening in the papilla.

The ova also develop in the interstitial tissue, near the proximal or aboral end (Fig. 10, *o*). There, in one or two separate projections of the ectoderm, cells increase, and free nuclei appear in the surrounding intercellular protoplasm. In each projection, one central, amœboid, vacuolated cell containing granules and vitellin particles increases in size, and a nucleus or germinal vesicle appears within it, around a germinal spot (Fig. 11, C). Green pigment grains, and sharply-contoured, round masses (pseudo-cells), like the yelk granules of a spongilla-egg, develop within this cell. After these form, the germinal vesicle becomes indistinct. They are fertilized *in situ*, the head of the spermatozoön touching the outer wall of the egg; whereupon the yelk segments, each part exhibiting amœboid motions, and the egg becomes a morula, whose inner cells are polygonal and the outer cylindrical. The outer surface of the egg is at first smooth, then becomes rough with irregular projections, and dark. The cylinder cells

exhibit a double contour, due to the formation of an outer, thin, chitinous (?) cuticle, between which and the central mass a fluid layer is interposed. The ovum now is set free, and the central yelk cells fuse into a plasmodium, which divides into a clear ectoderm and a darker endoderm. The horny cuticle splits, and is shed; hence the adult has no cuticle. The germ becomes ellipsoidal, clear at one pole, where by gradual thinning it develops a mouth, surrounded by 4-7 tubercles, which become tentacles, into which the endoderm is prolonged. The embryo has thus no free ciliated stage.

Hydræ thus produced never develop sex-organs, but multiply by gemmation or fission for several generations before new sex-products are formed. We have thus a perfect alternation of generations.

To this group belong the voracious freshwater Hydra viridis (Fig. 11, D), aurantiaca (Fig. 10), grisea, &c., differing in colour, size, and lengths of tentacles.

Protohydra Leuckarti (*Greef*)—a marine, non-tentaculated form, found in the diatom slime of the Ostend oyster park, also belongs here; it has no distinct cell-membrane, nor pigment in its ectoderm, but large cnidæ and a cuticle. Neither sexual nor gemmative reproduction have been found, but it multiplies freely by fission. It may be a larval form.

CHAPTER XIII.

HYDROZOA.

ORDER 2. Gymnoblastea (*Allman*). — In the last group, continuous aggregation is a temporary condition, but in the other orders the colony is the commonest state of existence. Each colony has a root (hydrorhiza) attached to some sub-aquatic body; from this arises a simple or branched tubular, cœnosarcal stem (hydrocaulus). These two parts

make up the hydrophyton. The wall of the tubular *somatic cavity* is composed of endo- and ecto-derm, covered by a chitinous, unorganized sheath (periderm), a differentiation or secretion from the ectoderm. In Hydra, the zooids which produce the sexual products are similar to those which do not; but in these orders the nutritive and generative zooids are dissimilar. All the nutritive zooids of a colony, taken together, constitute the *trophosome;* all the generative, the *gonosome;* either set may be homomorphic (similar) or heteromorphic (dissimilar). Each zooid of the trophosome is somewhat like a Hydra, and is called a hydranth (or polypite),* the distal end of which is prolonged into a proboscis (hypostome), at whose extremity is the mouth, and around whose base are the tentacles, often irregularly scattered, and varying from 2 (Lar) to 100 or more. The cavities of the tentacles are either divided by horizontal partitions (septate), or else obliterated (Coryne). The endoderm and ectoderm are separated by a thin, hyaline, supporting membrane, lying on the endodermal side of the muscular layer (*Schulze*). The endoderm is ciliated in many forms.

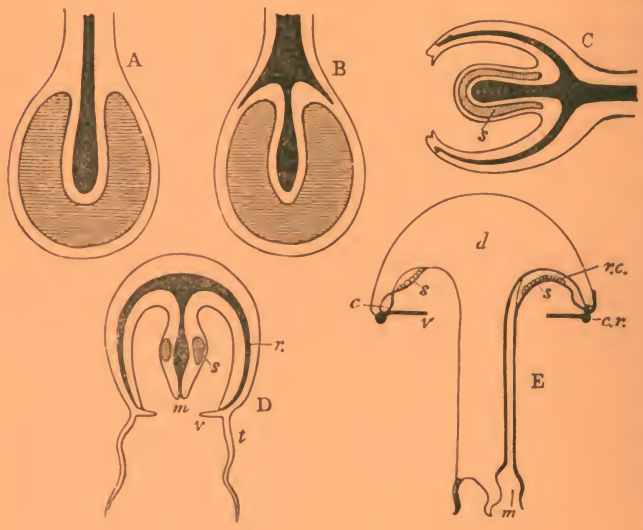
If the hydrocaulus be cut in a living colony, the distal end of the proximal segment develops a hydranth, while the cut end of the distal portion only forms an extension of the cœnosarc.

The gonosome is more variable than the trophosome, and consists of modified hydranths budding from the cœnosarc; these may be sessile closed sacs (sporosacs), consisting of a process of the ectoderm and

* Hydranths of some Tubulariæ become free, but only as a first stage of decadence; they never undergo any after metamorphoses.

endoderm, with a pouch of the somatic cavity contained (Fig. 12, A), and are said to be adelocodonic (*a*, δηλος, κωδων). The wall or perigonium of the sac consists of three layers derived from the ectoderm

Fig. 12.



A. Sporosac. B. Sporosac with incipient radial canals. C. Phanerocodonic gonophore; *s.*, spadix. D. Gonocheme, section; *r.c.*, radial canal; *m.* mouth; *v.*, velum; *t.*, tentacle; *s.*, sexual products. E. Carmarina hastata; *m.*, mouth, with tongue-like process; *d.*, disk; *c.*, circular canal; *s.*, sporosacs; *c.r.*, cartilaginous ring; *v.*, velum.

(ecto-, meso-, and endo-theca), having in the centre a tubular, cylindroidal stalk of the endoderm (spadix, Fig. 12, C, *s.*), on whose wall, under the endotheca, the sexual products form. From the somatic cavity in the base of the spadix, four radial canals lined by endoderm may traverse the mesotheca (homologous with that part of the tentacles of a hydranth included in the base of the hypostome, seen in section in Fig.

12, B & C). Many zooids undergo further change, and losing the ectotheca, the free pole of the mesotheca opens, forming a bell, with the spadix (now called manubrium) enclosed as a clapper (Fig. 12, D), and its cavity, opening at its extremity, forms a mouth (Fig. 12, D, *m.*) communicating with the stomach or cavity of the manubrium, and through it with the radial canals (Fig. 12, D, *r.c.*), whose peripheric ends become united by a circular canal (E, *c.*) around the margin of the mouth of the bell or codonostome. These tubes are called the gastro-vascular canals.* From the free edge of the codonostome, tentacles project (*t.*), and an in-growing muscular horizontal *velum* (*v.*) narrows the aperture. This form of zooid is called phanerocodonic, and it usually loses the pedicle joining it to the cœnosarc, becomes free, and is called a planoblast or medusa.† Ova or spermatozoa may develop under the ectodermal layer of its manubrium (Fig. 12, D, *s.*), and it is then called a gonocheme; but often the medusa produces along its radial canals, within the cavity of the bell, a second race of zooids, usually sporosacs (Fig. 12, E, *s.*), in which the sexual products are formed. Such medusæ are called blastochemes, and the second race are either saccular, or, as in Tima, a long wavy tube along the entire radial canal. To any of the zooids in which ova or spermatozoa are formed, the name gonophore has been given. A columnar zooid supporting gonophores along its side is named a blastostyle. The manubrium of a free medusa is homologous with the hypostome of the

* A circular lip below the stomach can, by contracting, temporarily shut off these canals from the stomach.

† Most of the small floating umbrella-like Jelly fishes, abundant in our seas, usually from the size of a pea to that of a walnut, belong to this class.

hydranth, and may be clavate, cylindrical, or long and ribbon-like (Sarsia strangulata).

No form exhibits adelo- or phanero-codonic gonophores indifferently, but each has its specific gonophore. The umbrella-like bell, in free forms, is contractile (except in Clavatella, &c.), and by it the zooid swims; hence it is called a nectocalyx. Dicoryne, however, moves by cilia, not by a contractile bell. The tissues making up this bell are:—1st. A layer of tesselated epithelium on its surface. 2nd. Loose connective tissue, either homogeneous or with fine fibres, containing neither collagen nor mucin, but sometimes with stellate corpuscles. When homogeneous, it is described as being epidermal in origin, and the fibres, &c., are considered ingrowths from the deeper connective layer. This makes the chief mass of the bell, but so little solid matter exists in these masses of "animated sea water," that each 100 grains, when dried, usually contains 2.50 grains of residuum, and from 10 kilogrammes of an allied form, only 30 grammes of solid matter were extracted. 3rd. Smooth, rarely monilated muscle fibres (?) in the velum and lining of the bell-cavity. In a few forms the submuscular connective tissue develops into a cartilage-like (Fig. 12, E, *c.r.*) ring, below the circular canal, parallel to the codonostome, and receiving the nerve ring; or radial rib-like cartilage rods, equalling in number the lithocysts, may lie in the outer surface of the bell (some Geryonidæ), or as a rod-like axis in the stiff tentacles (some Trachynemidæ, &c.) The gastrovascular canals may be below, or imbedded in, the connective tissue of the bell.

The marginal tentacles are usually simple, often

long, tubular, or septate and contractile. In their bulbous bases, imbedded in the ectoderm of the gonochemes, are masses of black or red, homogeneous, pigment spherules (*ocelli*), often with a clear, reflecting body immersed, and sometimes with a nerve ganglion at their bases. Around the margin of the bell in blastochemes, in the mid-spaces between the tentacles, or sometimes irregularly distributed, are *lithocysts*, or sacculi, containing one or more, rounded, concentrically laminated masses of calcium carbonate (or phosphate, *Haeckel*), rarely crystals, as in Cunina. These bodies are longitudinally striated, and sometimes (Geryonidæ) a ganglion lies under each sac, and fine hairs go to the concretion. In Tiaropsis, a pigment spot exists at the base of the lithocyst, but otherwise ocelli and lithocysts do not co-exist. Some lithocysts are pedunculated, and a canal from the marginal vessel passes into each, ending in an ampulla, below which is the vesicle containing the otolith. Ocelli rarely occur in blastochemes (except in Thaumantias, &c.); nor lithocysts in gonochemes (except in Goodsirea); Melicertum (a blastocheme) has neither.

Fine bristles (touch-organs) are found in the epithelium over the ganglionic swellings at the bases of the lithocysts in Cunina, and over the tentacles in Rhopalonema. The nerve system may consist of a ring connecting these ganglia, and true nerve cells have been found in the latter. Radial and interradial nerves may pass from these; but in general this system is obscure, scarcely detectible.

The relation between the gonophore and the hydranth has been proved teratologically. *Agassiz* saw the sporosac of Rhizogeton, having discharged its

contents, elongating, developing tentacles, and becoming a hydranth. *Allman* saw the same in Cordylophora. Blastostyles may pass into hydranths, as in Hydractinia polyclinia, where the blastostyle has a mouth, but no tentacles; in some Eudendria, the young blastostyle has tentacles, but loses them when the gonophores are developed.

The ova and spermatozoa are produced usually in different gonophores; the former by modifications of the interstitial* endodermal, the latter of the ectoderm cells (except in some Geryonidæ). The ova are impregnated within their sacs, and undergo segmentation as usual, and the embryo resulting is either cylindrical, ciliated, and infusorium-like (planula, Fig. 9, A), or polypoid, free, non-ciliated (actinula). The planula becomes flask-shaped, its wide end forming a hydrorhiza; the narrow end rises into a hydrocaulus, and finally develops a hydranth. The actinula swims for a few days by the contraction of its body, then settles down, forms a mouth, and becomes a hydranth. Sometimes a planula develops directly into a medusa with no hydroid trophosome (Cunina, *M'Crady*; Carmarina, Ægineta, and Æginopsis, *Metschnikoff*; Lizzia, *Claparède*).

The alternation of generations may be binary (hydranth, gonophore, + hydranth, gonophore, &c.), or ternary (hydranth, blastostyle, gonophore, + h., b., g., &c.), or quaternary (hydranth, blastostyle, blastocheme, gonocheme, + h., b., b., g., &c.); or even more complex if the hydranths be heteromorphic. The succession is, as a rule, constant in each species; and no subse-

* The testis in Hydractinia and Tubularia is certainly ectodermal (*Kleinenberg* and *E. Van Beneden*), while the eggs are endodermal.

quent non-sexual factor ever develops its antecedent. In some cases, planoblasts have been observed to produce heteromorphic buds unlike their parents; thus *Haeckel* describes Cuninæ as produced by budding from medusæ of the family Geryonidæ. To this process, which is not yet understood, the name Alleogenesis has been given.

Medusæ can be multiplied by artificial division; even when cut into a hundred pieces, each became a perfect medusa (*Haeckel*).

Gymnoblastea are divided into the following families:*—

1. Clavidæ—hydrocaulus rudimental or developed; hydranths club-like, with scattered filiform tentacles; sporosacs fixed, sessile, or shortly stalked. In Tubiclava, the hydrocaulus is developed. Cordylophora, the only freshwater form, has fusiform polypites at the extremities of a branched cœnosarc, and sporosacs on the hydrocaulus, each with a branched spadix. 2. Turridæ—hydrocaulus and hydranths as last; planoblasts,† with simple radiating canals, and simple marginal tentacles. In Campaniclavá, the hydrocaulus is undeveloped, and the planoblast is bitentaculate. In Turris the nectocalyx has striped muscular fibres, and each marginal tentacle has a bulbous ocellated base. 3. Corynidæ—hydranths with scattered, often spirally arranged, capitate tentacles, and fixed sporosacs; hydrocaulus developed, ex. Coryne. 4. Syncorynidæ—hydranths with scattered, or partly scattered, partly verticillate, capitate tentacles, with gonochemes, formerly known as Sarsia, with a simple mouth, four radial canals, and marginal tentacles, ex. Syncoryne. 5. Dicorynidæ—hydrocaulus invested with a perisarc; hydranths with verticillate filiform tentacles; planoblasts natatory, ciliated, with two simple basal tentacles, ex. Dicoryne.

* Classification is a matter of some difficulty, as similar gonosomes may be associated with dissimilar trophosomes (Isogonism); or dissimilar gonosomes may spring from similar trophosomes (Heterogonism).

† *Carus* calls planoblastic medusoids, parydrodea.

6. Bimeridæ—hydrocaulus with a perisarc, or rudimental; hydranths without an abruptly differentiated hypostome; tentacles filiform, in a whorl around the base of the mouth; sporosacs fixed, ex. Bimeria. 7. Bougainvillidæ—hydrocaulus with a perisarc; hydranths as last; tentacles filiform in a single circlet around the base of the hypostome; gonophores phanerocodonic, with four radial canals; marginal tentacles simple or clustered, ex. Bougainvillea. 8. Eudendridæ—hydrocaulus as last; hydranths with an abruptly differentiated peristome, and one circlet of simple verticillate tentacles; sporosacs fixed, ex. Eudendrium. 9. Hydractinidæ—hydrophyton forming a continuous expansion, its deeper part being a series of freely communicating tubes of cœnosarc, covered by a chitinous perisarc; hydranths, with filiform verticillate tentacles; sporosacs fixed. In the female sporosacs, there is a rudimental ectodermal male invagination, and in the male sporosacs, the endoderm forms rudimental and aborted ova, ex. Hydractinia. 10. Podocorynidæ—hydrophyton an adherent expansion of adnate, inosculating tubes, with a chitinous perisarc; gonophores phanerocodonic, ex. Podocoryne. 11. Cladonemidæ—hydrocaulus developed, invested by a perisarc; hydranths with two kinds of tentacles, filiform and capitate; the phanerocodonic gonophores have more than four radial canals, and branched marginal tentacles, ex. Cladonema. 12. Nemopsidæ—hydranths with a proximal and distal circlet of filiform tentacles; planoblasts often blastochemes, with four canals, and clustered dissimilar marginal tentacles, ex. Nemopsis. 13. Pennariadæ—hydrocaulus developed or none; hydranths with filiform and capitate tentacles; planoblasts with four canals and 1-4 marginal tentacles, ex. Pennaria. 14. Cladocorynidæ—hydranths with both simple *and branched* capitate tentacles; gonosome unknown, ex. Cladocoryne. 15. Myriothelidæ—hydranth solitary; hydrocaulus none; tentacles scattered, capitate; sporosacs on processes from the body of the hydranth, ex. Arum. 16. Clavatellidæ—hydranths with simple, verticillate, capitate tentacles; gonophores are ambulatory medusæ, with undeveloped umbrella, and branching marginal tentacles, ex. Clavatella. 17. Corymorphidæ—solitary; hydrocaulus with no perisarc;

hydranth with proximal and distal rows of filiform tentacles; planoblasts with one or more simple marginal tentacles, ex. Corymorpha. 18. Monocaulidæ—solitary, naked; hydrocaulus with hydranths, as last, and fixed sporosacs, ex. Monocaulis. 19. Hybocodonidæ—hydranths as last; hydrocaulus with a perisarc; planoblasts medusiform, ex. Hybocodon. 20. Tubularidæ—hydranths with two rows of tentacles; hydrocaulus with a perisarc; sporosacs fixed or planoblastic (*Carus*); hypostome conical. Some forms periodically shed their hydranths, ex. Tubularia. 21. Hydrolaridæ—hydrocaulus undeveloped; hydranths with two filiform tentacles from one side of the base of the bilabiate hypostome, which has a head-like lobe; planoblasts with six radial canals and simple marginal tentacles. The trophosome of Lar is very singular in form.

CHAPTER XIV.

HYDROZOA.

ORDER 3. Calyptoblastea (*Allman*).—Colonial forms, having the periderm expanded at the base of each hydranth into a cup or receptacle (hydrotheca); sometimes with a lid or operculum. The gonophores are at first included in a similar capsule (gonangium), which may hold one gonophore (monomeric), or many on a blastostyle (polymeric). Blastochemes, exceptional in the last order (Nemopsis), are common here (Campanularidæ); and sometimes the gonangia are clustered within a common receptacle (corbula). The gonophores may discharge their contents into the sea, or into the cavity of the gonangium, or into a sac at the summit of this cavity, and external to it (acrocyst,

an extension of the endotheca protruded as a pouch through the summit of the gonangium). Gonothyraea has, above the opercular summit of the gonangium, two pedicellate, spherical, medusiform gonophores (meconidia), with 8-20 circumoral tentacles and radial canals.

This includes the following families :—

1. Campanularidæ—with terminal, seldom stalked, operculate hydrothecæ ; hypostome trumpet-like ; blastochemes (Eucope, Obelia) or sporosacs (Campanularia, Clytia, Hincksia, Laomedea). 2. Campanulinidæ—hydrothecæ ovate, operculate ; polypites cylindrical ; hypostome small, conical ; blastochemes (Campanulina, Calycella). 3. Leptoscyphidæ—hydrothecæ oval ; the ocellated gonochemes are known as Lizzia, ex. Leptoscyphus. 4. Æquoridæ—hydrothecæ operculate, the lid of converging lanceolate segments ; blastochemes discoidal, with (Mesonema, &c.) or without oral tentacles (Æquorea), and with many radial canals. Stomobrachium sometimes undergoes fission, and has fine retiform canals in the muscular lining of the sub-umbrella (*Wright*). 5. Lafoeidæ—hydrothecæ tubular ; polypites cylindrical ; proboscis conical, ex. Lafoea. 6. Trachydridæ—hydrothecæ rudimental ; polypites cylindrical ; proboscis extensile, conical. 7. Thaumantiadæ—hydrothecæ non-operculate ; hypostome trumpet-like ; blastochemes, with shallow stomachs ; tentacles often numerous (200 in Tiaropsis), or dissimilar. 8. Coppiniadæ—hydrothecæ united by an encrusting cellular mass. 9. Lineolaridæ—hydrothecæ sessile, tubular, with oviform, sessile gonangia. 10. Sertulariadæ—sea-firs ; hydrothecæ sessile, inserted on the stems and branches of the hydrocaulus ; polypites retractile, with one circlet of filiform tentacles ; sporosacs fixed. 11. Haleciidæ—hydrothecæ none, or rudimental, biserial, sub-sessile, joined to a lateral process from the stem ; polypites not, or partly, retractile ; blastostyles, bearing the sex-products (not in sporosacs), develop within modified single internodes of the stem (pseudogonangia), each of which bears a hydranth (*Allman*), ex. Halecium. 12. Plumularidæ—hydrocaulus bearing, besides the ordinary

sessile unilateral hydrotheca, scattered degraded hydranths, consisting of cup-like cavities of the perisarc filled with protoplasm, in which nettle-cells are embedded, forming nettle-batteries or nematophores, for the protection of the colony; gonozooids fixed,* simple, axillary, ex. Plumularia.

Order 4. Monopsea (*Allman*)—Possibly only a provisional order, including those forms with no known trophosome separate from blastochemes, and in which the medusæ develop directly from the egg.

Four families are included :—

1. Geryonidæ—manubrium elongated; lithocysts intertentacular; sex-organs in flat masses along the radial canals, which may be four (Liriopinæ) or six (Geryoninæ); in the former there are no centripetal canals, often a tongue-like process, and eight (Xanthea) or four tentacles (Liriope); or no tongue-like process, and eight (Glossoconus) or four tentacles (Glossocodon). In the latter there are many blind centripetal canals, with (Carmarina, Fig. 12, E), or without a central tongue-like process (Geryonia), except in Leuckartia, where these canals are absent. 2. Æginidæ—disc with tentacles springing above the margin; radial canals, pouch-like, wide 4–32; lithocysts marginal; Cunina has simple tentacles, each with a conical cartilage at the base, springing opposite the stomach pouches (in Ægina they alternate), and a broad simple mouth. Æginopsis, which has oral tentacles, has been traced from its egg with no trophosome stage. *Agassiz* makes a separate family Brandtidæ for allied, but imperfectly known forms. 3. Trachynemidæ—blastochemes with no long manubrium, and stiff tentacles; disc bell-shaped (Trachynema), or flat (Rhopalonema). 4. Octorchidæ—with a solid quadrangular manubrium, having a radial canal at each angle, and eight genital masses, four in the manubrium and four in the sub-umbrella, ex. Octorchis.

* The protoplasm of the nematophore has been seen to protrude pseudopodia (*Allman*). These processes are sufficiently constant to be used in classifying the Plumulariæ (*Kirchenpauer*). Antennaria antennula has no nettle-cells.

Order 5. Milleporidæ—trophosome colonial, encrusting submerged materials in tropical and subtropical seas; massive or lamellar, often antler-like, branching, calcified; tentacles four; cœnenchyma abundant; tabulæ transverse. Only two genera survive: Millepora, with an irregularly tubular structure; and Heliopora, with tubular cœnenchyma and twelve regular septa, forming coral-like masses. Possibly the extinct Rugosa and Favositidæ should be included here (*Agassiz*). The reproductive zooids of all are unknown.

CHAPTER XV.

HYDROZOA.

SUB-CLASS 2. Siphonophora (*Eschscholtz*) — Free, oceanic, often bilateral or asymmetrical, with a muscle-bearing, flexible cænosarc, whose proximal end is dilated, containing an enlargement of the somatic cavity, often acting as a hydrostatic apparatus, and usually bears barren, medusiform zooids, specialized into swimming bells (nectocalyces). The ova are fertilized directly, and the germinal vesicle does not disappear in the early stages of development. The gonophores are medusiform, borne on the peduncles of the polypites. About 120 species exist, divided into two orders :—

Order 1. Calycophoridæ (*Leuckart*)—having the hydrosoma propelled by nectocalyces, each of which resembles the bell of a planoblastic medusa without a

manubrium, but retaining its veil. The cavity of the bell (nectosac) is lined by a muscular lamina, and the pedicle of the nectocalyx has in it a process of the body cavity, branching into four or eight nectocalycine canals (like the gastro-vascular canals of a gonophore). Between the proximal nectocalyces is a groove (hydrœcium) for the proximal end of the cœnosarc, within which it can be wholly or partially retracted. The cœnosarc is flexible, unbranched, contractile, filiform, never invested by a periderm. The proximal end of the somatic cavity dilates in front of the nectocalyces into a variously shaped cavity (somatocyst), ciliated within, containing large, refracting globules, often air bubbles, and a vacuolated endoderm, often nearly closing the cavity. Each polypite has a narrow peduncle (proximal part), and consists of a wide, gastric portion, ciliated and villous within, at whose opening into the peduncle there is an endodermal fold (pyloric valve). The distal end of each polypite is the hypostome. Coloured hepatic cells may line part of the gastric wall (Praya), and cnidæ exist among the villi of the endoderm. The single so-called tentacle of each polypite arises from the peduncle, and is a modified zooid consisting of a slender basal "pedicle," a middle thick part or "sacculus," the equivalent of the manubrium, armed with cnidæ, and a terminal, often coiled, "filament." The pedicle may expand where it joins the sacculus, and when this dilatation encloses the base of the second part it is called the involucre, and is a modified medusa bell. A muscular angle-band (*Leuckart*), folded in zigzags, lies on the hinder wall of the sacculus; its proximal end passes into the pedicle, its distal into the filament. The peduncle of the polypite

often bears a protective leaf-like appendage (hydrophyllium), made of a layer of ectoderm, a process of endoderm, and a pouch of the somatic cavity (phyllocyst). These may be thin (Diphyes), or thick (Abyla), on the cœnosarc, or on the peduncle of the polypite. The gonophores bud from the peduncle, and may become planoblastic; sometimes each carries with it a segment of the cœnosarc (which breaks midway between each group), supporting a polypite, tentacle, and hydrophyllium. Such detached parts are called Diphyozoöids, and they move by the contraction of the gonocalyx of the medusiform gonophore. The cœnosarc grows at the proximal end, so that the oldest polypites are farthest from the somatocyst.

There are four families:—

1. Diphyidæ—with two polygonal nectocalyces, the hydrœcium of the proximal being complete; hydrophyllia large. In Diphyes the proximal nectocalyx is mitrate, pentagonal in transverse section, and larger than the distal; the hydrophyllia are spathiform, smooth; the diphyozoöids are known as Aglaisma, Eudoxia, &c. In Abyla, the proximal nectocalyx is small, polyhedral, the distal large and mitrate; the hydrophyllia are thick and facetted; its detached parts are called Diplophysa, Amphiroa, &c. 2. Sphaeronectidæ—nectocalyx single, spheroidal, with a complete hydrœcium; hydrophyllia none; tentacle attached to the peduncle, ex. Sphaeronectes. 3. Prayidæ—nectocalyces two, parallel, with incomplete or groove-like hydrœcia; phyllocyst prolonged into four cœcal processes in the thick, reniform, gelatinous hydrophyllia; male and female medusoids attached to the same cœnosarc, ex. Praya. 4. Hippopodidæ—nectocalyces many, horse-shoe shaped (Hippopodium), or many-angled (Vogtia), with incomplete hydroecium, and no hydrophyllia.

Order 2. Physophoridæ (*Eschscholtz*).—Siphonophora, with the proximal end of the somatic cavity

expanded into a variously shaped pneumatophore, containing at its apex a chitinous air-sac (pneumatocyst), which does not communicate with the cavity of the pneumatophore, or with the somatic cavity, but opens externally by a pore or *stigma* (except in Physophora, Forskalia, Agalma, Athorybia, and Halistemma), and is held in its place by a reflection of the endoderm. Its shape may be spheroidal (Athorybia), oval (Physophora), cylindrical and small (Agalma), &c. The hydrophyllia and tentacles are as in Calycophoridæ; and there are also, on the cœnosarc, *hydrocysts*, polypoid, protective, or prehensile processes of endo- and ectoderm, each with one long, filiform tentacle, closed distally, and profusely armed with trichocysts. The tentacles may be simple cœcal tubes with vacuolated endoderm (Velella), or branched at the end (Porpita). Each may be at the base of a polypite (Apolemia), or projecting from the cœnosarc independently of the polypites, each with a basal sac (Physalia). In Physophora, the tentacle has a large, spheroidal involucre enclosing the sacculus. From the air-sac to the wall of the pneumatophore, septiform processes pass in Forskålia and Agalma. In Velella, slender, jointed, air-holding processes project from the pneumatocyst into the wall of the hepatic organ (pneumatic filaments). In Rhizophysa, long, branched, cellular processes, covered by ciliated endoderm, project from the wall of the pneumatocyst into the cavity of the pneumatophore; perhaps like the hepatic organ of Velella.

The medusiform buds form on blastostyles, and are often free; males (androphores) and females (gynophores) may co-exist, or be separate. The appendages on the cœnosarc are usually unilateral.

There are seven families, viz. :—

1. Apolemiadæ—possessing nectocalyces; hydrophyllia, with the other organs, arranged in groups at intervals along the filiform cœnosarc; pneumatocyst small; tentacles with no lateral branches; gonophore free, ex. Apolemia. 2. Stephanomiadæ—having nectocalyces; hydrophyllia, with the other organs, in a continuous series on the filiform cœnosarc; tentacles with lateral branches ending in sacculi; pneumatocyst small; the sacculi may have no involucre, and a single filament with biserial (Halistemma) or multiserial (Forskalia), nectocalyces, and (especially in the former) a complex muscular apparatus in the tentacles, or the lateral branches of the tentacles may be involucrate with one (Stephanomia) or two filaments, with a pouch-like middle lobe between; in this case, the cœnosarc is sometimes highly contractile, with leaf-like thin hydrophyllia, and polypites dispersed spirally on the cœnosarc. Stinging filaments surround the stem on all sides (Agalmopsis); or the stem may be rigid, and not very contractile, with thick wedge-like hydrophyllia one over another (Agalma). In Crystallodes, the cœnosarc is rigid, and the polypites simply arranged on its ventral side, the tentacles being between the hydrophyllia. 3. Physophoridæ—nectocalyces in a double row (2 – 5 pairs), each channeled internally to fit the cœnosarc, and with four radial and a circular uniting canal. There is no pneumatocystic stigma, nor hydrophyllium, but an apical pigment spot in the pneumatophore, and a series of proximal hydrocysts, with or without filiform tentacles, ex. Physophora, Stephanospira. 4. Athorybiadæ—nectocalyces, none; the globular cavity of the cœnosarc nearly filled with the large pneumatocyst; hydrophyllia on the proximal side of the other appendages; tentacular branches with involucral sacculi; two filaments, and a median fluid-holding lobe, ex. Athorybia. 5. Rhizophysidæ—cœnosarc filiform; nectocalyces and hydrophyllia none; pneumatocyst small, in a pear-shaped pneumatophore, and with a red patch at its stigma, through which the sac can expel the contained air; the tentacles have lateral branches, but no sacculi nor muscle-bands, ex. Rhizophysa. 6. Physaliadæ—hydrosoma pear-shaped, with no hydrophyllia nor nectocalyces; cœnosarc

irregular, thick, with a crest formed of ectoderm on the upper surface; having a horizontal, long air-sac between its layers, divided alternately by smaller and larger transverse muscular septa; the long tentacles have basal sacs, but no lateral branches, and at intervals along their outer wall there are kidney-shaped enlargements, armed with cnidæ and an internal muscle-band, ex. Physalia, the Portuguese man-of-war. 7. Vellelidæ—with no hydrophyllia nor nectocalyces; short submarginal tentacles; a single central polypite below the flattened, strong, chitinous pneumatocyst, which is divided into chambers by concentric partitions, and occupies the whole cœnosarc; the pneumatic cells of the air-sac communicate with each other by openings in the septa, two into each chamber; there are also external stigmata, six in the vertical plate and about seven in the horizontal; the soft ectoderm is permeated by ciliated canals; the hepatic organ is made up of deep brown cells, lining the branchings of the gastrovascular canals, and opening radially (Porpita), or in two series into the stomach (Velella). The genera are:—Velella—oblong, with a solid vertical crest (with oblique surface markings) crossing the disc diagonally; reproductive zooids planoblastic (Chrysomitra). Porpita—discoidal, with branched tentacles, and no crest; it has a spongy, guanin-containing body below the pneumatocyst, possibly an excretory organ.

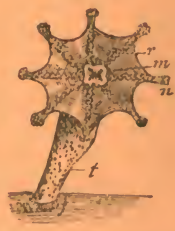
Order 3. Graptolitidæ.—Palaeozoic Hydrozoa with a free, compound, often branched, hydrosoma, and uni- or bilateral hydrothecæ containing nematophores, which were probably nutritive; some had a horny, basal pneumatophore; other parts are unknown.

Sub-class 3. Calycozoa (*Leuckart*, Podactinaria, *M. Edwards*)—stalked, oceanic forms, capable of attachment by an aboral disc (Fig. 13, *f*). The generative elements lie in symmetrical, band-like projections of the inner surface of the somatic cavity, and are discharged into it.

There is one order and family, Lucernaridæ, which

has a body like an inverted bell, with a medial, square mouth on a projecting proboscis or hypostome. This bell is fixed on a pillar, and can detach its aboral disc, and creep by its suckers, or swim like a Discophoran. The body cavity is four-chambered. At the margins of the disc are often lithocysts and clusters of tentacles, either suctorial, adhesive, or similar to those of Medusæ, placed on the angles (Lucernaria, Fig. 13), or in the intervals between the angles (Depastrum) of the octagonal disc; or the margin may be entire, with the tentacles in several (1 – 3) rows (Carduella, Calycinaria). There are wide radial canals passing from the marginal suckers to the stomach. The reproductive elements arise in these tubes, extending to the edge in Depastrum and Lucernaria, not in Carduella. Development is direct. They live in the N. Atlantic Ocean.

Fig. 13.



Lucernaria auricula; *f*, disc of attachment; *t*, body; *m*, mouth; *n*, cluster of suctorial tentacles; *r*, generative elements.

CHAPTER XVI.

HYDROZOA.

SUB-CLASS 4. Discophora (*Eschscholtz*).—Free, oceanic forms, with a basal *umbrella*, which is not a mesothecal expansion of the base of a manubrium, and has no velum, but is traversed by not fewer than eight branching, anastomosing canals, and bears sense-organs in marginal notches (Fig. 14). Reproductive organs in symmetrical pouch-like dilatations of the body cavity.

Two orders are included herein:—

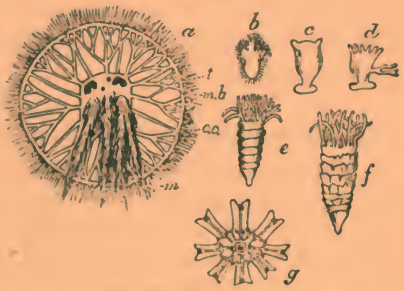
1. Rhizostomida—Reproductive organs in free zoöids, with no marginal tentacles nor central mouth, but with a tree-like mass depending from the umbrella, bearing many, mouth-like openings, formed by the irregular gaps produced by the contact and adhesion of complexly folded oral lobes.

Fig. 14.

Marginal body of Chabydæa marsupialis, showing its stalk cavity, two lenticular bodies (eyes), and one lithocyst below.

In this order, and the next, the young embryo on emission from the egg is a planula (Fig. 15, *b*), which, after a short locomotive period, attaches itself by its narrow end to some solid body, and forms a mouth and stomach by invagination at its distal end, around which four rudimental tentacles develop (15, *c*); these elongate, and others form in their intervals. This hydra-like form lengthens, its mouth extends into a manubrium-like process, and longitudinal canals sketch from the mouth to the wall of the body.

Fig. 15.



a, Aurelia aurita; *b*, development of Aurelia aurita, planula; *c*, Hydra tuba; *d*, Hydra tuba budding; *e*, Scyphistoma; *f*, Strobila; *g*, Ephyra; *t*, tentacles; *m. b.* marginal bodies; *c. c.* circular canal.

This trophosome having lived for a variable time (*c.d.*), the elongated wall of the *hydra tuba* (as it is called) becomes marked by a series of transverse grooves (*e*) around its circumference, which deepen, dividing the tube into a series of superposed discs, like

a pile of saucers. In this "scyphistoma" stage, the segments become more and more separable, each saucer becoming lobate round its margin, and then the column is called a strobila (*f*); finally, each separates as a free swimming disc or ephyra (*g*), which by degrees assumes its adult form, swims by the contractions of its umbrella, and develops ova and spermatozoa in its genital pouches. The young free zooids of Rhizostomidæ have a single central mouth (*Brandt*), but as the oral lobes increase in the complexity of their folds, and as these folds irregularly cohere, they produce the irregular polystomous, oral lobes, characteristic of the adult (*stomatodendra*). A degree of bilateral symmetry may be noticed in some Rhizostomidæ, and clavate tentacles are scattered upon the oral lobes. The bases of the stomatodendra unite into a *syndendrium*, attached by four stout processes or *dendrostyles* to the under surface of the umbrella, between which are the genital pouches.

The order Rhizostomida includes six families :—

1. Rhizostomidæ—with four genital pouches, opening by as many sub-genital pores; eyeclusters eight, four in the meridians of the arm-roots (per-radial), and four inter-radial; stomatodendra much curled, leaf like, forming sucking combs, ex. Rhizostoma, Mastigias, &c. 2. Leptobrachidæ—with four genital pouches, and four sub-genital pores; single, thin, unbranched stomatodendra, without tentacles, with one tuft of border-plaits and suckers, ex. Leptobrachia. 3. Cassiopeiïdæ—with eight genital pouches, and sub-genital pores; eight ocelli; no tentacles; arms forming an eight-rayed rosette, of dendritic tufts; ex. Cassiopeia, Crossotoma, &c. 4. Polyclonidæ—with four genital pouches, and sub-genital pores; stomatodendra long, continuously dichotomously twigged; no long tentacles; twelve ocelli, four per-radial, and one on each side of each of these (ad-radial), ex. Polyclonia, Sala-

mis. 5. Cepheïdæ—with four genital pouches, and sub-genital pores; short, complex stomatodendra, with sucking mouths between the terminal twigs; tentacles long, thin; eyes eight; ex. Cephea, Cotylorhiza. 6. Crambessidæ—with one central, cross-shaped genital pouch over the stomach, and four sub-genital pores; arms unbranched, with no tentacles, but with many rows of isolated, wrinkled, capitate, sucking knobs; four per-radial, and four inter-radial eyes; ex. Crambessa.

2. Pelagiada—Discophorans with marginal tentacles, containing processes of the anastomosing somatic canals around the umbrella margin. The trophosome may be fixed, but producing free gonosomes; or free, developing its sex-organs in its own umbrella. The mouth is central; the gastrovascular system consists of pouch-like processes.

There are three families:—

1. Charybdæidæ—with no marginal canal, simple mouth-pillar, and branching lateral canals. The tentacles may be four (Charybdæa), or four bundles (Tamoya). The former genus has a lenticular eye-mass (Fig. 14), and pigment spot, imbedded in its pillared lithocyst, into which latter a pouch of the lateral canal is prolonged. 2. Pelagiïdæ—with a marginal canal; mouth-pillar, with four long, lobate (Chrysaora) or leaf-like lobes around the mouth (Pelagia), or simple, four-angled (Nausithoë). There are no radial branched canals, and eight or twelve to twenty-four marginal tentacles (Chrysaora); when eight they may (Nausithoë), or may not, alternate with sense-organs. 3. Medusidæ—mouth-pillar unbranched, lobed; stomach with or without pouches; radial canals branched, and with a marginal canal. The marginal tentacles may be very many (Aurelia, Fig. 15), or few, or none; in the latter cases there may be eight (Sthenonia), or sixteen (Phacellophora), or very numerous bundles of tentacles on the under side of the disc (Cyanea). The stomach is four-pouched in the last genus.

CHAPTER XVII.

CTENOPHORA (*Eschscholtz*).

SUB-CLASS 5. CTENOPHORA.*—Transparent, pelagic, gelatinous forms, radially and bilaterally symmetrical; moving by meridional, comb-like rows of ciliated, ectodermal swimming plates (ctenophores), between which are interspaces or ctenomeres. There are usually eight of these (four in Cestum, twelve in Alcinoë); each plate is thick, and movable by muscle at the base; thinner, but rigid to the ciliated edge, where the central cilia are longer than the lateral. Towards each pole of the often ovoidal or spheroidal body the ctenophoral ridges end in rows of cilia, narrowing finally to a point. The mouth is simple, or with raised edges, at one end (oral pole), and opens into a fusiform, tubular stomach, lined with coloured hepatic (?) cells. From this passes a wide, short funnel, to the apical pole, where it ends by two anal openings (apical pores); or may be closed (Cestum?). This pole is usually uppermost in swimming. From the base of the funnel arise two paragastric canals, which pass one at each side of the stomach, towards the oral pole; and below these there are two or four others (primary radial canals) passing horizontally; these (if two) bifurcate into secondary radial canals, each of the four ending in a pair of tertiary canals; one of these passes out to beneath each row of swimming plates, and is there continued from pole to pole

* This possibly should be a class, equivalent to Hydrozoa, and intermediate between Discophora and Echinodermata; to the latter of which it has many affinities (*Agassiz*).

under the ridge, as a ctenophoral canal. In some, *e. g.* Beroë, paragastric and ctenophoral canals open into a circular vessel around the mouth, and the radial canals are obsolete. The whole tubular system is lined by ciliated endoderm.

Retractile, hollow tentacles exist in Pleurobrachia, one at each side, in sacs about the equator of the body. These are fringed with smaller cirrhi, and here alone thread cells are developed, often in clusters. Into these tentacles radial canals extend. The parenchyma consists of connective tissue like that of medusæ, and a layer of meridional and transverse interlacing muscular fibres lies superficially, which can to some extent alter the body-shape, but does not act in locomotion. In Beroë, lateral secreting organs exist as small bladders, only visible when full; many such exist in Cestum.

In Chiajea, *Will* has described a second vascular system, but this has not been confirmed.

At the apical pole is a spherical vesicle (ctenocyst, absent in Eurhamphœa), lined by ciliated epithelium, and containing a pigment mass in Bolina, Idya, Pleurobrachia, and an otolith, to which stiff hairs pass from the epithelium (acoustic hairs). In Eschscholtzia there are two pigment masses beside the ctenocyst. Near this pole also are two oblong apical areas, surrounded by branched threads, or covered with hollow, shaggy processes; probably areas of sensation, as a nerve extends to them.

A ganglion is placed between the apical canals of the funnel, sending off filaments along the ctenophoral ridges, as well as in the wall of the funnel and stomach. *Grant* describes a circum-oral ring, and something like this is described by Eimer.

They are hermaphrodites, and the sexual products arise in folds or pouches of the radial canals, the ova at one side, and the spermatozoa at the other. The ova are expelled by the mouth at all seasons of the year, and develop usually with no metagenetic forms. At first only four ctenophores exist, as in the non-ciliated Eucharis; some may have a larval stage, such as the Cellephobe of *Busch*. In development the ctenophoral canals arise as offshoots from the endodermal cavity, and the gastro-vascular lobes appear at first as solid cellular cords. There may be also in the embryo provisional oral lobes, &c., like the permanent auriculæ of some forms.

There are over one hundred species, mostly small; Chiajea being the giant of the sub-class. They are distributed in four orders.

1. Eurystomata (*Leuckart*)—oval, wide-mouthed, with no appendages, and a circum-oral canal. This includes the families Beroïdæ, with entire margins at each pole, the apical end being either conically extensile (Beroë), or not (Idyia); Neisidæ with a compressed apical pole, which is deeply notched, and unequal ctenophores; Rangidæ with a deeply notched oral pole.

2. Saccatæ (*Agassiz*)—no circum-oral vessel; tentacles two, turned from the mouth; ctenophores sub-equal or equal. The families are:—Pleurobrachidæ, with no lateral folds, and a symmetrical, round, or oval body, having the ctenophores reaching from pole to pole (Pleurobrachia), or only $\frac{1}{2}$ or $\frac{2}{3}$ of the meridian, and the tentacles with simple (Eschscholtzia), complex (Hormiphora) or no appendages (Dryodea); Mertensidæ have broad, often heart-shaped, bodies, with unequal ctenophores and simple tentacles (Hæckelia), or equal ctenophores prolonged on processes at the apical pole (Gegenbauria), or with rounded sides (Mertensia); Callianiridæ are cylindrical, winged at the oral pole.

3. Tæniatæ (*Agassiz*)—ribbon-like, with no oral lobes; tentacles two, turned to the mouth. There is one family,

Cestidæ, including the Venus' girdle (Cestum), with a long stomach, and Vexillum with a larger funnel.

4. Lobatæ (*Eschscholtz*)—body with a pair of antero-posterior lobate processes; ridges and ctenophoral canals of unequal length. The families are: Eurhamphœidæ—with beak-like apical, lobate, oral pole and no tentacles; Bolinidæ—with rounded apical pole, small tentacles not in sacs, and with the four shorter radial ridges in pairs, smooth on the surface (Bolina), or papillose (Bolinopsis); Mnemiidæ—with oral lobes separated from the lateral parts of the body by grooves, and two of the radial canals ending in arabesque convolutions in the oral lobes. Eucharis and Chiajea are papillose, the others are smooth, with large (Mnemiopsis), or small auricles (Mnemia, Lesueuria); Calymmidæ—with lobate processes arising from the apical end, overlapping the oral end as a mantle; Ocyroidæ—with forked lobes prolonged from the apical end.

The aberrant Sicyosoma (*Gegenbaur*), with no ctenophores nor gastrovascular canals, but with nettle cells in the body wall, may form a fifth order, or may be the young of Cestum (*Agassiz*), or an Actinian larva (*Krohn* and *Leückart*).

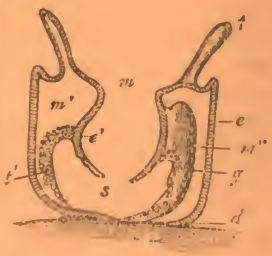
CHAPTER XVIII.

Class 2. Actinozoa.

Radiated cœlenterates with tentacles (Fig. 17, *t*) round the mouth at the distal pole, and with a stomach cavity separate from, suspended within, and opening into, the body cavity (*s*), the portion of which around the stomach (perivisceral space) is divided into compartments by vertical, radiating, membranous partitions, mesenteries (Fig. 17, *m'*), in which the sex-organs are developed. Thus in transverse

section an actinozoon appears as two concentric tubes, whose walls are joined by the radial mesenteries, while a hydrozoon appears as a single tube. Striped muscle, several forms of connective and gland tissue exist in some; but they have no nervous nor vascular system. The ectoderm consists of two laminæ, an outer, ecderon or epidermis, of epithelium, pigment, clear irregular gland cells, and trichocysts with bebristled filaments, growing from within outwards; and an inner, enderon, growing from without inwards, made of granular, striated connective tissue. The endoderm consists of a muscular layer of circular and longitudinal fibres (the former strongly developed in the tentacles and around the mouth; this stratum may be intermediate or ectodermal in origin), a connective lamina, and an internal ciliated epithelium. The tentacles are hollow, contractile, or fully retractile, lined by endoderm, and both sensitive and prehensile; between these and the mouth is a peristomial space. The mesenteries are arranged in several orders successively developed: primary, reaching from the body to the stomach wall; secondary, not extending to the stomach, and placed between the primaries, &c.

Fig. 16.



Section of Sea Anemone; *m*, mouth; *m'*, primary mesentery; *m''*, secondary mesentery; *e*, ectoderm; *e'*, endoderm; *t*, tentacle; *g*, generative element; *d*, disc; *s*, body cavity.

A skeleton may be formed in the ectoderm by the inclusion of sponge spicules and other foreign bodies (Sagartia Schilleriana, Heterozoanthus), but usually by the deposits of calcium carbonate in the connective laminæ. These deposits may be (1) discontinuous, of small, definitely shaped, spicular bodies, as in Alcyonidæ; or (2) continuous, coherent skele-

tons, which may be (α) isolated, or amalgamated with a horny* or chalky interstitial substance (axis of Melithæa, &c.), or (β) lamellated, with or without an organic basis (as Gorgonia or Primnoa), or (γ) crystalline, increasing by chalky deposits, with scarcely an organic basis (Madrepores). Spicules (Sclerodermites) are fusiform, laminar, ovoid, or stellate; a spicular skeleton is a *polypieroid;* one continuously calcified, a *polyparium* or *corallum;*† the hard tissue is Sclerenchyma, which may be compact or porous. Each persona (Corallite) of a polyparium consists of some of the following parts:—1. A calcified, ab-oral *foot*, continued in colonial forms into the cœnenchyma. 2. The calcified enderon of the persona (*theca*) forming the wall of the cup (*calyx*); this may consist of two layers, an endo- and an exotheca. 3. Calcified mesenteries (*septa*‡), passing in from the endotheca, dividing the calyx longitudinally into radially-arranged loculi. 4. Rib-like ridges on the outside of the exotheca, opposite each system or between two (*costae*). 5. Outside the exotheca, an ecderonic investing layer or *epitheca* may form, often developed in inverse ratio to the thickness of the theca. 6. Between the simple zooids of a

* Apparently horny, but really chitinoid; intermediate between Chitin and Keratin.

† Analysis of Coral gives 89–96 per cent. of Calcium Carbonate; 0·3–250 of Calcium and Magnesium Phosphate and Fluoride; 0·50 organic basis with traces of Silica, Iron, Alumina. Magnesium Floride is present in Pœcilopora. There is, however, much variety. Silica may in some cases reach 25 per cent.; Magnesia, 45 per cent. The specific gravity of Coral averages from 2·20–2·80.

‡ Septa grows in cycles, the five or six primary folds form the first, the secondary the second (also of five or six). Between these a third cycle forms, of twelve laminæ, one in each interval. The fourth cycle consists of two orders of septa, one between every first and third, and one of still shorter plates between the second and third. The fifth cycle consists of three orders: one of shorter plates than the fifth order, between those of the first and fourth; a seventh order between the second and fifth; an eighth between the third and fourth, &c. Each order after the third cycle consists of twelve laminæ; so when a whorl consists of eight orders they will follow each other thus:—1, 6, 4, 3, 8, 5, 7, 2, 7, 5, 8, 3, 4, 6, 1, &c.

colony there is ofteu an ecderonic tubular or laminar connecting material (*peritheca*), often as horizontal plates uniting the zooids (*epithecal dissepiments*). 7. A central *columella* may form in the middle of each calyx, corresponding to the enderon forming the floor of the somatic cavity below the stomach; when this is a distinct pillar it is called *columella propria;* when it consists of the centrally united septa, it is *c. septalis* or *pseudocolumella.* 8. Smaller detached rods around the columella, formed of the dismemberments of septa (*pali* or *bacilli*). 9. Short transverse bars may unite one septum to its neighbours (*synapticulæ*). 10. Horizontal plates growing inwards from the sides of the septa (*endothecal dissepiments*) may divide the chambers into storeys; when these are complete they are called *tabulæ.* A central pillar-like elevation of the tabulæ is a *columella parietalis.* The presence of a coralllum precludes locomotion.

The stomach wall often contains pigment (hepatic) cells. The somatic cavity extends as a canal system into the cœnenchyma; within it chyle corpuscles circulate in a vehicle of sea water, which enters by the mouth, and is expelled through the pores at the tips or sides of the tentacles. On the mesenteries are richly ciliated coiled threads (craspeda) containing guanin, and consisting of an axis, often a central closed canal, and a peripheric layer armed with thread cells: these may protrude through small openings (cinclides); sometimes found in rows on the body wall, through which sometimes the chylaqueous fluid escapes from the body cavity.

Reproduction is sexual, the sexes being separate or united. The ova and spermatozoa arise along the borders of the mesenteric folds, and when immature the sexes can only be distinguished by the microscope. The ova are fertilized in the body cavity, and the ciliated planuliform larvæ are expelled by the mouth.

Fission may also occur, and may be imperfect, vertical, producing cæspitose, or horizontal, producing lamellar masses. Buds may also form, and may be basogenic (from the base of the parent), stoloniferous (from basal stolons), perigenic (from the sides of the parietal cœnenchyma), or calycular, arising inside the cup of the parent.

There are two sub-classes:—1. Zoantharia (Hexactinia)—having the mesenteries and simple, rarely branched tentacles, in multiples of six (or five); the former are in pairs; some or all of them bear longitudinal muscular bands (vanes); around the mouth is often an annular canal communicating with the several perivisceral spaces; they are marine, and have no central horny axis in their cœnenchyma, except in Antipathidæ.

Three orders are included:—1. Malacodermata—sea anemones; rarely colonial, with either no corallum or a few spicules; the body cavity is distended by water, which can be expelled on irritation, causing a rapid collapse; the tentacles are numerous, the sexes separate (except Sagartia troglodytes), the body cylindrical, and the craspeda developed. They can be multiplied by artificial division; the embryos are planuliform, then become ovate, and settling down (sometimes in eight days), a mouth forms at the larger end; the wall of the digestive sac forms as a ring around the mouth, which grows down into the body cavity.* At first the tentacles are five or six, and the mesenteries as many, but they increase in number rapidly. They live for several years. One kept by *Dalyell* for six years produced 276 young. In the

* This is either a down growth or an invagination.

China Sea they have been found up to three feet in diameter, and containing Clupeoid fishes as commensals (*Collingwood*).

Three families exist:—1. Zoanthidæ—the only colonial forms, with a creeping, leathery, filiform, spiculigerous cœnosarc; zooids united by a flat, root-like mass of stolons (Palythoa), or by basilar budding (Zoanthus). The tentacles are in several cycles, each one communicating with one segment of the perivisceral cavity. Foreign bodies may be enclosed in the cœnosarc (Heterozoanthus).

2. Cerianthidæ—hermaphrodite; with no spicules; tentacles in two concentric circles, not alternate, two communicating with each intermesenteric space. The mesenteries do not extend to the hinder end, and in the young there are only four. The aboral end is pointed, perforate (Cerianthus), or imperforate (Saccanthus). In the former, two mesenteries extend farther than the others, and a deep, gutter-like groove continues along its body cavity to its foot. It throws off a slough of thread cells and mucus, mixed with foreign bodies. Saccanthus has equal mesenteries.

3. Actiniidæ—separate personæ, with many series of tentacles; stomach with two lateral grooves (cartilaginous in Sphenopus). This includes four sub-families:—Minyadinæ—having the foot dilated into a rounded air-holding sac; the body may be warted (Minyas) or smooth, with simple (Plotactis) or lobed tentacles (Nautactis). Actininæ—foot with a muscular sole (sucking disc); tentacles conical, often uniform, not retractile (Anthea) or retractile (Actinia). The mouth may have two long lips (Actinopsis), or several crispate lobes (Metridium), or a trifid lip (Siphonactinia). A few are rounded, or pointed distally, and free swimming; of these, Peachia and Halcacampa have a distal perforation. Milnea and Arachnactis are rounded, and the former has a median epidermic girdle; Ilyanthus is pointed, imperforate; cinclides are numerous, and often wart-like in Cribrina, Sagartia, Adamsia, &c. Phyllactinæ—tentacles both simple and lobate, the latter in an outer cycle (Phyllactis), or between two series of simple ones (Rhodactis). Ulactis has a warted body.

Thalassianthinæ—tentacles all compound, outer hooked, papillose (Heterodactyla), or the inner with rounded warts (Sarcophianthus). The stem of the branched tentacles may be warty (Phymanthus), or filamented (Actineria); the branches may be pear-shaped (Actinodendron), or feathery (Thalassianthe).

Order 2. Sclerodermata (Madreporaria)—colonies, rarely simple; skeleton enderonic, continuous, calcareous, with hexameral symmetry (tetrameral in Rugosa). This includes the reef-building corals of past and present ages.

The following sub-orders are included:—1. Rugosa (surmised to belong to Hydrozoa allied to Milleporidæ), Palaeozoic* with thecæ, complete tabulæ and rudimental, or perfect imperforate septa, without synapticulæ; in multiples of four. They have no true cœnenchyma, and increase by parietal or calycular budding, not by fission. Four families are contained:—1. Stauridæ—simple or branched, with incomplete septa, united by lamellar dissepiments, the four primary septa forming a cross. 2. Cyathaxonidæ—simple, with complete septa and one septal groove; dissepiments and tabulæ none. 3. Cystiphyllidæ—simple, vesicular, with slight septa, and bladder-like endotheca; sometimes an operculum to the calyx. 4. Cyathophyllidæ—simple or branched, with incomplete septa and tabulæ; endothecæ closing the chambers; columella present (Axophyllinae), or none; septa regular (Cyathophyllinæ), or irregular (Zaphrentinæ). The Devonian Calceola has an operculum of one, Goniophyllum of four valves.

Sub-order 2. Tabulata—hexameral corals with tabulæ and few imperfect septa, including the families:—1. Seriatoporidæ—tree-like; cœnenchyma abundant, compact; septa weak or bacillar; tabulæ few; chambers filled by the thick wall and columella; palaeozoic, except the Red Sea Seriatopora. 2. Favositidæ—tabulæ strong; thecæ united to their neighbours, with little or no cœnenchyma; Pœcilopora is the

* Except the Cretaceous and Eocene Stauridian genus Holocystis.

only living genus; these are referred by some to Hydrozoa. 3. Thecidæ—Palæozoic; thick, massive; tabulæ many; septa not reaching the centre, but uniting peripherally into a dense spurious cœnenchyma.

Sub-order 3. Tubulosa—Palaeozoic corals with a simple pyriform (Pyrgia) or connected (Aulopora) colony with no columella nor tabulæ, and striæ representing septa, and with an imperforate theca. In Aulopora the cœnenchyma is basal.

Sub-order 4. Perforata—corals with a porous or netted cœnenchyma, with no tabulæ, well-developed septa, and rudimental dissepiments; thecæ not costate. This includes the families:—1. Madreporidæ—compound with thick, simply porous thecæ, not distinct from the cœnenchyma; chief radii little or not at all perforated; two strong septa may reach the middle (Madrepora), or a spongiose columella may exist with closely converging laminæ (Eupsammidæ). Turbinarinæ have six strong septa developed without (Astræopora), or with a columella (Turbinaria). 2. Poritidæ have no lamellar septa, but trabeculæ or bacilli form a netted skeleton; the calyces may have rudimental dissepiments; cœnenchyma either netted, spongy, separate (Alveopora), or indistinguishable from the calyces (Psammocora), or else rudimental or none (Poritinæ).

Sub-order 5. Aporosa—with an imperforate (except in family 7), compact, lamellar sclerenchyma; strong, rarely perforate septa; well developed, often costate thecæ; chambers open for their whole extent, or partly closed by dissepiments or synapticulæ; thecæ and septa better developed than in other corals. This includes eight families:—1. Turbinolidæ—simple; multiplying by fission or budding; no cœnenchyma, dissepiments, nor synapticulæ (except in Cœnocyathus); surface granular. A columella may or may not exist, and when present it may be surrounded by one (Caryophyllinæ), or many (Trochocyathinæ), or no circlets of bacilli. 2. Dasmiidæ—Eocene corals with each septum made up of three lamella attached to the costate thecæ. 3. Stylophoridæ have abundant loose spinose cœnenchyma; septa large, and costæ strong; central cavity interrupted, not filled by dissepiments; gemmation irregularly lateral. 4. Oculi-

nidæ—tree-like; loculi divided by a few dissepiments, obliterating part of the calyx; budding lateral; cœnenchyma abundant, not distinct from the thecæ; septa generally few, usually with a columella; costæ as striations or granules; septa may be unequal (Oculininæ), or equal (Stylasterinæ), with (Axohelia) or without costæ; pali may form one (Sclerohelia) or more circlets around the columella, or this last may be absent (Trymohelia). 5. Astraeidæ—single or compound, with no true cœnenchyma nor synapticulæ; each theca joined directly to its neighbour, or united by its largely developed costæ, or by exothecal dissepiments; endothecal dissepiments numerous at the base; septa many, often incomplete within, smooth (Eusmilinæ) or spinose (Astraeinæ); the former group may have single corallites (Trochosmilia), or many multiply by incomplete fission (Euphylliaceæ), or gemmation (Stylinaceæ). Astraeinæ contains five groups: Lithophylliacea—simple, cœspitose or labyrinthose; Faviaceæ reproducing fissiparously, each calyx retaining its individuality; Astræacea massive, reproducing by gemmation; Cladocoraceæ—tree-like, budding laterally; Astrangiaceæ budding from stolons, or from the base, with short stocks. 6. Echinoporidæ—lamellar; gemmation sub-basilar; corallites united at base by a spinose cœnenchyma. 7. Merulinidæ, with no cœnenchyma nor synapticulæ; theca perforate, with dissepiments; septa imperforate. 8. Fungiidæ—simple or compound; thecæ feeble, porous, or none, with no dissepiments nor tabulæ, and many wart-like or spinose synapticulæ; gemmation basal; the septa are porous, toothed, or echinulated along their free edges, as are the thecæ in Funginæ, not in Lophoserinæ.

Order 3. Antipatharia (*Edwards*, Sclerobasica).—Colonial forms with no sclerodermic deposits of lime, but a solid, often black, axis (sclerobasis). The zooids have six short broad tentacles.

Sometimes the cœnenchyma contains siliceous bodies, rendering it granular (Leiopathes); its branches may unite into a network (Arachnopathes), or fan (Rhipidopathes), or

remain free (Antipathes), or the unbranched axis may be spirally twisted (Cirrhopathes). About thirty species are known, mostly from deep Palæarctic sea bottoms.

Sclerodermic corals only exist in clear sea water, unmixed with freshwater, where the winter temperature does not sink below 66° F., and usually between the limits of 1–30 fathoms.

Three forms of reef exist:—1. Barrier reefs, girdling continents or islands, at a distance from land. 2. Fringing reefs, surrounding islands, only separated therefrom by shallow channels, and sloping seaward. 3. Atolls, or circular coral islands, with a lagoon in the centre. The first and last forms grow on a gradually subsiding, the second on a gradually rising, sea bottom.

CHAPTER XIX.

ALCYONARIA.

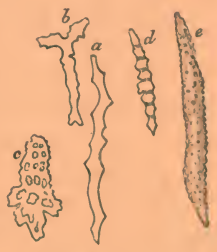
SUB-CLASS 2. Alcyonaria (*Edwards*, Octactinia, *Ehrenberg*).—Actinozoa, with eight short, broad, pinnately-fringed tentacles, and mesenteries in multiples of four; usually with spicules, but no continuous enderonic skeleton. When the outer skeleton is continuous, it is epithecal, and there may be centrally a sclerobasic axis or a tubular system. The eight septa are not in pairs, nor do they bear longitudinal bands of muscle. The following orders are contained:—

1. Alcyonaceæ—Sclerobasis none; ectoderm leathery, with no epitheca, but with calcareous spicules. The

somatic cavities of the polyps extend into the cœnosarc as a communicating tubular system, into which the mesenteric folds extend. The sex organs develop on these, as in Zoantharia, and craspeda are often present.

Three families are contained:—1. Cornulariidæ—rarely simple (Haimeia with retractile polyps and a simple tube; Hartea,* with stellate basal, and branched tentacular spicules), generally compound, increasing by basal budding or by stolons; in the former case, the spicules may be fusiform, or cylindrical, spiny or tuberous, and the polyps retractile (Sympodium†), or non retractile (Anthelia); the outer layer may be smooth and the polyps retractile (Lobularia). The stoloniferous forms may have non-retractile, wart-like calyces and a creeping, thick cœnosarc (Sarcodictyum). The polyps may be tubular, non-retractile (Rhizoxenia), or retractile, ribbed and spiculigerous (Clavularia), or smooth, non-spiculigerous (Cornularia). 2. Telestidæ—compound, increasing to a tree-like colony by lateral budding, ex. Telesto. 3. Alcyonidæ—lobate or branched masses, formed by lateral budding, often granular on the surface. Alcyonium is fleshy, lobate, with retractile polyps on all sides; Sarcophytum has a discoidal pedicellated polypieroid, barren beneath; Ammothea has semi-retractile zooids; Belonella is capitate, with plaited-mouthed zooids; Xenia has clustered, non-retractile polypes on the ends of the branches of a soft, slightly-branched cœnosarc; Nidalia has a cartilaginous, cylindrical stem, with fusiform spicules, the zooids on the upper surface of a hemispherical head; Spongodes has a membranous, cellular, outer surface covered by opaque, fusiform spicules; Nephthya has a branched, coriaceous, granu-

Fig. 17.



Spicules of Alcyonidæ; *a*, *b*, Telesto Africana; *c*, Muricea granulosa; *d*, Alcyonium digitatum; *e*, Paralcyonium elegans.

* This may be an immature form of Alcyonium (*Wright*).

† This may belong to Briareaceæ.

lated cœnosarc, with large external spicules, and sub-cylindrical incurved polyp-cells; Paralcyonium is membranous, branched, with large dermal spicules at the base, the somatic cavities opening freely into each other.

Order 2. Tubiporaceæ (organ-pipe corals of the Indian Ocean)—sclerobasis none; the purple-red epitheca is tubular, made of consolidated spicules (*Wright*); the tubes are united by table-like, calcified, perithecal dissepiments, from which new tubes bud; the eight green tentacles have oval lenticular spicules; the central mouth has a circular lip. On irritation, the tentacles first close together, then the whole polyps sinks into the tube. The stomach has delicate walls, ex. Tubipora.

Order 3. Pennatulaceæ (sea-pens)—sclerobase soft, free-swimming, or sand-embedded, of calcified, horny matter, traversed by soft radial bands. The lower part of this axis is barren; the upper, or *pars polypifera*, is variably branched, and its ectoderm is spiculigerous (except in Halisceptrum and Lygus).* Three kinds of zooids may exist:—1. Nutritive, tentaculate. 2. Sexual, non-tentaculate. 3. Rudimental, neither sexual nor tentaculate.

There are three families:—1. Pennatulidæ—feather-shaped colonies; polyps along the margins of the pinnately-branched axis; pars polypifera bilaterally symmetrical. In these, the principal zooids may reach the fleshy pinnæ, and the spicules may be fascicular (Pteroides), or the zooids are on the ventral side of the rachis, with the spicules scattered (Pennatula), or none (Halisceptrum, Sceptonidium). The pars polypifera may be narrow, and the pinnæ short, with no spicules (Virgularia, Lygus), or with a spicular plate below the pinnæ (Stylatura); or the zooids may be on a thick ridge of the

* *Richiardi* gives the name Zoanthodema to the cœnosarc.

quadrangular rachis, with spiculigerous tentacles, and no pinnæ (Pavonaria); or on thick pinnæ alone (Scytalium). Funiculina and Halipterus have no pinnæ; the former has dorsal zooids and eight-toothed calyces along its rod-like axis; the latter has lateral zooids with two-toothed cups. Umbellularia has a long sterile axis, and the zooids, at first simple, symmetrical, become grouped (20–30) in an umbrella at the upper end. Pennatula and some of its allies are luminous, the light inhering in eight cords, consisting of vesicles containing fat and multipolar cells (*Panceri*), on the outer surface of the stomach of the zooids, continued in the buccal membrane.

2. Renillidæ have a kidney-shaped, parenchymatous, laminar stock (a single pinnule), with the retractile zooids on one side; no solid axis.

3. Veretillidæ—axis elongated, quadrangular, having retractile zooids on its entire surface; its lower part bulbous, naked (Lituaria), or soft; longitudinally divided into four tubes by two intersecting membranes, with a calcareous axis in the lower part of the stem (Cavernularia); or simple, fleshy, with a rudimental, membranous (Sarcobelemnon), or boat-shaped axis. A primordial Australian form (Pseudogorgia Godefroyi) has simple rows of polyps, each on a warty projection of the polypieroid, and no trace of an inner, horny, or calcareous axis, but a broad, single, central canal, a prolongation of the combined somatic cavities. There are two long, slender, and six short, thick mesenteric filaments. This is a passage form to Briareaceæ.

Possibly the club-shaped Kophobelemnon, with thin calcareous axis, and no pinnules, should be the type of a separate family linking Veretillidæ to the true sea-pens.

Order 4. Gorgonaceæ—rooted; usually branched colonies with minutely-ridged, flexible sclerobase; often with characteristic enderonic spicules (dermosclerites); thecæ often operculate.

Three families are included:—1. Primnoidæ—cœnenchyma, with scaly sclerites, and club-like zoöid-bearing papillæ (Primnoa); or spinose, with boat-shaped spicules and

cylindrical papillæ (Muricea). In Primnoa, the operculum consists of three-pointed scales, and the axis consists of concentric, calcified, horny lamellæ, surrounded by alternate, non-spiculigerous rings of horny and crystalline calcareous matter.

2. Gorgonidæ—cœnenchyma smooth; axis horny, sometimes flat, leaf-like, with anastomosing branches forming small (Xiphigorgia) or large interstices, whose meshes are either open (Rhipidogorgia) or filled with soft cœnenchyma. In this case the sclerobase may be expanded into thin lamellæ (Phycogorgia); or round, with netted branches in the leaf-like cœnenchyma (Phyllogorgia*). In others, the branches are tree-like, not anastomosing; and the zoöids are disposed either regularly on both sides of the cœnosarc (Pterogorgia), or irregularly over its whole surface, which may be fan-like or tasseled (Lophogorgia). The zoöids are either sunk into the thick, corky (Plexaura), or skin-like (Leptogorgia) cœnenchyma, or project on warts, with rounded (Gorgonia) or bilabiate calyces (Eunicea). Plexaurella has spicules in laminæ between layers of horny matter. Sclerogorgia has an uncalcified, horny, spiculigerous axis.

3. Gorgonellidæ—axis corneo-calcareous, either straight, unilaterally comb-like (Ctenocella), or rod-like (Juncella), in structure like Plexaurella, but with spicules in the horny laminæ; or branched, with (Vermicella) or without projecting zoöids (Gorgonella). In the last, the horny lamellæ are concentric, calcified.

Order 5. Isidaceæ.—The axis consists of alternate, soft, and calcareous joints.

This includes two families:—Melithæidæ—soft joints, suberose, concentrically laminated; hard joints made of cemented spicules; branches arising sometimes from the horny joints, which may be traversed by tubular canals (Melithæa); Isididæ—hard joints of concentrically laminated, calcified membrane, traversed by radial lamellæ, but without spicules; soft joints horny, like the axis in Gorgonidæ;

* Hymenogorgia differs in having free branches.

branches arise from the calcareous (Isis) or horny joints (Mopsea). Parisis seems to be a passage form.

Order 6. Briareaceæ.—The axis is never horny, but may be hollow (Cœlogorgia), or filled with spongy tissue, with *siliceous* (Solanderia), or calcareous spicules (Briareus), and with large, nutritive canals, or none (Spongioderma). The polypes may be partly (Solenogorgia), or wholly retractile, either embedded in the cortex (Paragorgia), or in wart-like calyces (Briareus).

Order 7. Coralliaceæ—axis rigid, unjointed, calcareous, branched, finely grooved on the surface; coloured deep red by iron oxide, with little or no organic matter. This is coated by a red cœnosarc, traversed by the canals extending from the bodies of the retractile, white polyps. These canals have perforate walls, and contain a milky, corpusculated fluid. The precious red coral of the Mediterranean (Corallium rubrum) belongs here. It lies in 10–30 fathoms of water.

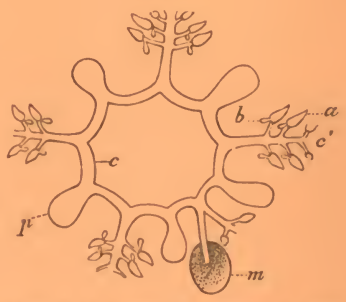
CHAPTER XX.

SUB-KINGDOM 4. ECHINODERMATA.

MARINE, never colonial animals; each made up of several (usually four or five) radially, often bilaterally, symmetrical antimeres. The integument has a ciliated outer layer, beneath which is a dermis containing calcified, never chitinous,

plates or spicules: this is called the perisome, and it often bears spines. The nervous system consists of a circum-oral filament, uniting the long, radially-divergent threads, which are coloured orange, brown, or green, by a pigment layer over the neurilemma. The ciliated digestive canal is separate from the cœloma or perivisceral cavity,* which is also ciliated, and contains sea-water. A peculiar set of water-holding canals exists (Fig. 18), separate from the digestive tract, although arising as an outgrowth from it, lined by ciliated protoplasm; this consists of a ring around the mouth, giving off radial branches (*c*), one or two in every antimere, each again giving off rows of small, hollow, muscular processes (ambulacra, or pedicelli *a*), which project on the surface, and by which the animal moves. This connexion of locomotion with the water-vascular system is characteristic. Attached to the circum-oral canal are also inter-radial sacs (Polian vesicles, Fig. 18, *p*), acting as reservoirs for the fluid (which is sea-water containing chyle corpuscles). *Agassiz* compares this system with the canals and tentacles of Cœlenterata.

Fig. 18.



Ambulacral system of Echinus; *a*, ambulacral pedicelli; *b*, sacculi; *c*, circum-oral ring; *p*, Polian-vesicle; *m*, madreporiform plate.

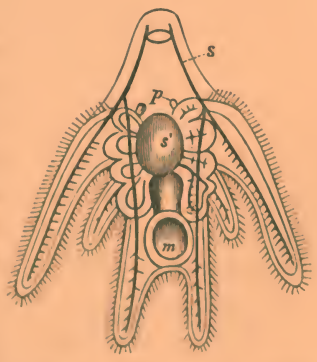
Muscular tissue is developed in the perisome in inverse proportion to its calcification; least in Echini,

* But this, as well as the water vascular system, is an outgrowth from the alimentary canal (*Metschnikoff* and *A. Agassiz*).

most in Holothuriæ. The fibres are usually unstriped, except in the jaw-muscles of Echinus, and the longitudinal bands in Synapta. A non-ciliated, pseudhæmal circulatory system exists in most species, consisting of a ring-like (arterial ?) canal, between the nervous and water-vascular rings around the œsophagus, with sometimes a second circum-anal (venous ?) circle, and a fusiform muscular heart, uniting the two circles.

The sexes are separate (except in Synapta, Molpadia, &c.) The eggs are small, consisting of a shell, albumen, and a fine-grained yelk; development begins by the disappearance of the germinal vesicle, and may be direct, but usually the egg produces a larva (pseudembryo, *W. Thomson*), of which (except in Crinoids and Holothurians) only the part around the digestive canal develops into the mature form, the rest being only provisional. This larva is bilaterally symmetrical, and resembles that of some of the Annulosa. In this stage all Echinoderms are somewhat like in structure. From the egg is emitted a ciliated planula, whose cilia become restricted to transverse or lateral bands, which often elongate into processes. A stomach and intestine form within, beginning as a pouch, convex backwards, opening at first by an anus, but soon developing a

Fig. 19.



Pluteus larva of Ophiolepis; *s*, skeleton; *p*, pedicelli; *s'*, stomach; *m*, mouth.

mouth. Close to this digestive tube a discoidal mass of protoplasm forms, first on one side, then extending around it; then, according to *Müller*, an involution of the integument at one side of the back forms a pouch, which narrows into a tube, whose fundus dilates, in the protoplasm around the stomach, into a rosette, extending around the œsophagus as a circular vessel, from which the rudiments of the ambulacral canals and pedicels arise. The primary involution narrows into a tube, the stone-canal or hydrophore, which leads from the outer ab-oral side into the ring-canal; its outer opening becomes closed by the formation of a perforated, often labyrinthically tubulated, calcareous scale, the madreporiform plate. The later researches of *Metschnikoff* and *Agassiz* indicate that the perivisceral cavity, as well as the ambulacral canals, are formed as offshoots from the digestive canal. A symmetrical larval skeleton of spicules may exist (except in Asteriadæ and Holothuriadæ), no part of which is transferred to the adult. When a cœloma exists in the larva, it is not continued into the perivisceral cavity of the adult.*

This sub-kingdom is divisible into three classes:—

CLASS 1. STELLERIDA—Starfishes, having a central disc, and usually 5–20 diverging arms. The peristome is not calcified through its entire thickness, and consists of:—1st, a leathery papillary layer, whose spinose process may be clustered, bristle-like points (paxillæ), or echinulated, one-jointed spines. 2nd, a

* Prof. Huxley originally united these and the Scolecida under the name Annuloida, a convenient, though unnatural, grouping, as the Echinoderms are Deuterostomes, while most of the Scolecides are Archæostomatous. Such a group would consist of animals with a separate alimentary canal, a water-vascular system, and a thread-like nervous system.

calcified* layer of many-jointed plates,† bounding a central, ambulacral groove on the under surface of the arms. The dorsal surface of the body is convex, and called antambulacral.

The mouth is central, inferior, often surrounded by flat spines or tooth-like processes; it opens into a central globular or pentagonal stomach in the centre of the disc, held in its place by radial mesenteries. The intestine is spiral, ending near the mouth (Comatula), or short, ending in a dorsal anus, or none (Ophiuridæ, Ctenodiscus, Llwydia, Astropecten). The circulatory organs consist of the circum-oral and circum-anal rings, and a pulsating heart. (*Fourdain* regards this as a gland, and the other pseudhæmal tubes as water-vascular.‡) For respiratory purposes, the sea-water not only bathes the surface, but enters the body cavity either by surface pores, or by the genital fissures (Ophiuridæ), or by inter-radial *laminæ cribrosæ* (Solaster, &c.), as well as by the porous madreporiform plate. When there are several of these plates, as in Echinaster, there have been several larval involutions of integument, and hence several stone-canals.

The pharyngeal nerve ring has few nerve cells, or none (Asteracanthion), and sends two threads covered with ganglion-cells (ambulacral brains) along each ambulacral space; these widen to the middle, and send branches to each joint of the calcareous axis. Muscular fibres lie between the joints of the skeleton, to assist in locomotion. The ambulacral system consists of a circum-oral ring,

* Containing a trace of Calcium Phosphate.

† Corresponding to the Auriculæ of Echinidæ.

‡ The existence of a separate circum-oral vascular ring has been recently denied.

Polian vesicles, and radial ambulacral canals with pedicelli. Each of the last is a muscular tube, ending externally in a foot and sucking disc, and having at its inner or attached end a canal for the ambulacral vessel, and an opening into a muscular ampulla or reservoir (Fig. 18, *b*). The foot consists of longitudinal and circular muscular fibre, covered by ciliated epithelium. Contraction of the ampulla and of the circular fibres extends the foot, which is contracted and retracted by the longitudinal fibres.

The sexual organs are grape-like pouches in the inter-radial spaces. Development is rarely direct, or viviparous. In common with all Echinoderms, they can reproduce lost parts.

This class contains six orders:—

1. Blastoidea (*Fleming*)—Palaeozoic, pentameral, armless, bud-like forms, fixed on a jointed, perforated, immovable stalk, with a central mouth, inter-radial genital pores, and with or without (Eleutherocrinus) an anus. The body (calyx) consists of thirteen plates in three circlets, the lowest of three unequal pentagonal basal tables; the second circle of five forked radial plates, between which are five trapezoidal, inter-radial plates. Above the calyx are five lancet-shaped ambulacral pieces, homologous to the sub-ambulacral plates of crinoids, fitting into the forks of the radial plates, and bearing pinnulæ along their margins; their surfaces are striated, and their margins perforated by pores. About fifty fossil species are known. They have large genital pores in five pairs, each over an inter-radial (Pentatremites), or over an ambulacral plate (Elœacrinus). The pores may be in three pairs and two single (Eleutherocrinus).

2. Cystoidea—Palaeozoic, pedicled, or sessile; body globular or polyhedral, rarely flattened (Agelacrinus), with a wall of many (often 1–2–300), sometimes porous, polygonal plates in radial zones; mouth central, surrounded by pinnules or weak arms, which may be fixed, or (rarely) free, pinnulated

(Comarocystis); anus always present; there were five lateral ovaries (?) with openings, when present, surrounded by five plates, almost always present; the pillar is short, jointed, or none. About 80 species are known as fossils. Hyponome, from Cape York, Australia—a small star-like free disc, ventrally convex, with no calyx, and a dorsal scaly rosette—is the nearest living ally, and approaches Agelacrinus.*

3. Crinoidea—stalked, at least in early life, with a cup-shaped body of calcareous plates, with from 2–18, but commonly five, solid, primary, often branching, arms, independent of the visceral cavity, except at the base, and furrowed longitudinally above for the tentacle-like pedicelli given off by the ambulacral tubes lying in these medial grooves radiating from the mouth. This system seems purely respiratory. The arms can move rapidly, and can close over the oral disc for protection; they have laterally articulated pinnules appended. The ventral surface is, as in the last order, upturned; the dorsal stalked.

The mouth is usually central, and in some fossil forms mounted on a proboscis. The ciliated stomach winds around a spongy calcareous spindle (compared to the lamina spiralis of the Mammalian cochlea). The anus may be ventral, between two water-vascular furrows, or absent (?) (Holopus). The digestive canal never extends into the arms. The pseudhæmal system consists of a central sacculus giving off branches to the arms. The ovaries are external, membranous lamellæ developed under the soft skin on the ventral surface of the pinnæ. The testes are similar, and the products emptied by dehiscence.

The column rises from a root-like disc, adherent to some solid body; sometimes several are rooted together. The pillar itself consists of superposed calcareous joints, traversed by a single or multiple axial canal. The joints are united by ligaments and interarticular laminæ of elastic vertical fibres, and in some there are bundles of unstriped muscle-fibres (none in Pentacrinus); here and there are whorls of jointed cirrhi. The basement material of the calcareous plates is a

* *Chapman* proposes an order Thyroidea for some forms which possibly linked these to Asteroidea, ex. Edriaster.

soft, flexible, connective tissue, which calcifies by the deposition of netted, calcareous bands, longitudinally and transversely. In Phytocrinus, the stalk at first bends spirally. The body consists of—1st (next the pillar), 2–5 *basal* plates forming the *pelvis*. 2nd, one or two circlets of *parabasal* plates. 3rd, several orders of *radial* plates along the lines of the arms; the upper surfaces of these have often two articular faces at an obtuse angle for the two arms (*radialia axillaria*). There may be also several orders of *inter-radial* plates. The arms are often branched; their joints may be free, or united by *syzygies* (immovable sutures). To these the pinnulæ, each of which receives a fine thread from the nerve, are laterally appended. The segments may be numerous; thus in Pentacrinus briareus there are five basals, fifteen radials, ten primary arms, each of seven joints, two secondary arms of 200 joints on each primary, eighteen hundred-jointed pinnæ on each secondary arm, and 36,000 ten-jointed pinnules.

The embryo begins as a free ciliated body, which elongates; a bundle of cilia projects at the anterior end; then it assumes somewhat the appearance of a four-jointed worm, at each segment of which is a ring of cilia; a calcareous network now forms in the wall, and a mouth develops, which, however, with the cilia is soon lost; the animal then becomes sessile, somewhat polypoid, develops knobs at its free end and an alimentary canal; the extended calcareous skeleton masks the growth of the viscera, and the embryo becomes opaque. Within the mouth a set of irregularly lobed gland masses, brownish in colour, and probably hepatic, appear. The pillar lengthens, and calcifies rapidly. There are about 600 fossil, and about 48 known living forms, divided into two families.

Encrinidæ—permanently stalked; calyx either of tables (Tesselata), all fossil forms, ex. Cyathocrinus, Poteriocrinus, &c., or with naked skin between the arms (Articulata). The surviving genera are:—1. Pentacrinus—with small calyx; ten strong, many-pinnulated arms; pillar joints five-lobed, with appended cirrhi; basals, 5; sub-radials, none; radials, 15; inter-radials, none. There are probably four species known. 2. Holopus—sessile, aproctous; basals, 4 (5, *Ag.*); radials, 4

(5, *Ag.*); arms long, close, four (five, *Ag.*) pair; these, like the last, are West Indian. 3. Ophiocrinus—with five undivided arms, sixteen ventral cirrhi, and no other ossicula. 4. Rhizocrinus—with a long, jointed column, and long rounded joints; calyx variable in its number of pieces; anus circular, midway between the mouth and the margin of the disc (North Atlantic).

Comatulidæ—feather stars; free when mature; stalked when young; body with immovable dorsal cirrhi of 2–180 joints, representing those of the stem in Pentacrinus; 10–40 pinnulated arms; anus ventral. They quickly pass through the early stages of development, when they appear as ovate bodies with four transverse rows of cilia, a keyhole-shaped mouth and an anus. The stalked condition has been named Phytocrinus. The genera are Antedon, the common feather-star, from which possibly Alecto may be distinct; and Phanogenia, with a simple stelliform centro-dorsal joint, and basal plates hidden, internal (from Malacca). Allied, are the fossils Hertha, Pterocoma, &c.

4. Ophiuroidea—brittle stars, with rounded or pentagonal flattened discs, and elongated arms differentiated from the body, and containing no viscera. The ambulacral pedicelli have no ampullæ nor sucking discs, and feet are developed medio-ventrally. Pedicellariæ are wanting. There is a calcified peristome of oral plates, grooved for the nerve ring, and armed with *palae angulares*, or spurious teeth, based on five small plates (*tori angulares**), one at each of the five angles of the mouth. The disc may be naked (Ophiomyxa, Ophioscolex); or covered with fine, hard, equal granules (Ophiocoma, Ophiarachna); or with shields (Ophiomastix); or granules and scales (Ophiothrix); or many large, symmetrical shields (Ophiolepis). The arms are special locomotive organs, each enclosed in four rows of plates, dorsal, ventral, and two lateral, within which is an axis of jointed, squarish, dermal, calcareous plates, separated from the ventral surface shields by the ambulacral vessel, and above the axis is the nerve cord. Each plate consists of two ankylosed halves, and there is a branch of the nerve and water vessel for each joint of the axis. The first pair of axial segments is large,

* Possibly homologous with the teeth of Echini (?)

with halves more separable than in the succeeding joints, and they are joined to their fellows of the other limbs so as to form a calcareous ring, enclosing the water-vascular circlet, whose ten branches to the oral tentacles pierce these plates. These hollow tentacles are in pairs at each angle of the mouth, one on each side of the radial water-vessel. The madreporiform plate is ventral, distinct, or more commonly covered by one of the oral plates. The stone-canal sometimes contains a free or attached pulpy mass. The Polian vesicles are four; one, which in Asteriadæ is anterior to the wall with the stone canal, being absent. Between the arms are genital fissures, through which the products of the interradial sexual glands escape, and the sea-water enters. The stomach is round or pentagonal, ciliated; the anus absent. A few are viviparous, and rapidly developed (Ophiolepis, squamata, and vivipara), but usually there is a free larval stage (Fig. 19). The ciliated ovum assumes a bilateral form, like a compressed eight-ribbed umbrella, which has, in each of its two lateral primary rays, a calcareous spicule (*s*), at whose base is a half circle also calcareous; from these diverge respectively two lower and two upper accessory rays, the latter of which bifurcate; thus there are eight diverging calcareous rods over which the homogeneous protoplasm is spread. Two little spines lie fore and aft where the calcareous basal semicircles unite. These spicules are in contact, but not ankylosed together. A central digestive canal forms (*s'*), appearing deep green from its contents; traces of the nerve cords next appear. The plasma around the stomach forms two longitudinal lateral folds, which unite as a lamina in front of the stomach, traversed by the pharynx; then a cup-like mass forms behind it; these represent respectively the ventral and dorsal faces of the perisome. The adult rays soon appear, grow, and become shielded. Then the lobate body of the larva breaks up, and atrophies, and, together with the skeleton, is lost, and the adult form is assumed. The free-swimming, pelagic larva of Ophiolepis ciliata is known as Pluteus paradoxus, that of O. Sundevallii as P. bimaculatus.

They are divisible into two families:—1. Euryalidæ—

genital fissures ten, two in each interbrachial space; arms not shielded, usually branched; abdominal groove closed by a soft skin. The genital fissures may be in pits between the oral shield, as in Asteronyx, which has the large disc and arms naked; or as in Asteromorpha, which has a granular disc and arms; or they may not be in pits, and the arms undivided and disc granulated (Asteroschema), or deeply annulated (Asteroporpa). The arms may be divided at the tips only (Trichaster), or branching from the base (Astrophyton). In Astrophyton verrucosum, there are over 200,000 joints in the arm-skeleton, each with two nerve threads and several muscles.

2. Ophiuridæ—arms unbranched, shielded; ventral grooves covered with plates; genital slits usually 5; madreporiform plate fused with one mouth-shield. This includes about thirty genera, in nine sub-families. Ophioderminæ—mouth-edge papillose; oral shields large; tori angulares and disc granulated; arms arising from notches in the disc; genital fissures 20 (Ophioderma, Ophiocnemis) or 10 (Ophiopeza, Ophiarachna). Ophioscolecinæ—disc naked; mouth-edge papillose; tooth papillæ none; spines smooth, imbedded; ambulacral papillæ present (Ophioblenna), or absent (Ophioscolex). Ophiomyxinæ—tooth papillæ present; mouth edge papillose; disc naked; arms scaly (Ophiarthrum) or naked, the tips only of the rough spines being free (Ophiomyxa). Ophiothricinæ—mouth fissure not papillose; disc with multangular spines (Ophionyx), or with granules, hairs, or spines, and hook-like spines on the arms (Ophiothrix). Ophiocominæ—mouth slit papillose; oral shields small, round; disc not notched for the arms; tooth papillæ present; disc granular; arm spines either constantly visible or seen when the body dries (Ophiopsila). Ophiacanthinae—like the last in many respects, with a shielded and granular disc, but with no tooth papillæ; arms with large lateral shields. Ophionereinæ—with no tooth papillæ; disc with minute shields; arms long, narrow at origin; radial shields covered. Amphiurinæ—with naked radial shields, and keeled lateral arm-scales. Ophiolepinæ—disc symmetrically shielded; tori angulares naked, not granular; mouth shields large; oral slit papillose. The

back of the arm insertion (which notches the disc) has a row of papillæ, either medially interrupted (Ophiura), or not (Ophiocten).

Order 5. Brisingoidea—passage forms, with the disc of Asteriadæ and the arms of Ophiuridæ; closely bristled, with eleven long cylindrical arms, separate from the disc, but containing short, single cœca from the stomach; anus subcentral; pedicellariæ present; madreporiform plate marginal, dorsal; genital glands limited to the middle of the arms, opening dorsally by two sets of pores. The open ambulacral grooves, which do not extend to the mouth, have two series of feet. The one species, Brisinga endecacnemos (*Asbjornsen*), is found on the Coast of Norway, as well as in the Southern Ocean.*

Order 6. Asteroidea—Starfishes having the arms continuous with the disc, being, in fact, its prolonged angles. The dorsal ant-ambulacral surface is covered by a coloured, leathery membrane, bearing bristles (paxillæ) and compound spines, sometimes moved by muscles. The madreporiform plate is conspicuous, dorsal; sometimes there are several, and as many stone-canals (five in Echinaster). In Pteraster, it lies with the anus in the floor of a sub-cutaneous dorsal pouch. The lower surface of each arm is medially grooved for the ambulacral feet, which are at least in double rows, and often bordered by warty papillæ (*papillæ sulcorum*). Under the leathery membrane is a dermal skeleton of many *vertebræ* or segments, each consisting of several pieces (*adambulacral*, *intermediate*, *ventro-marginal*, *uniting*, and *dorso-marginal*). In Astropecten, there are over 12,000 pieces; in Uraster, 11,000. Each arm possesses a muscular system, consisting of:—1st. Transverse fibres above and below each segment, joining together the two lateral halves, which are movable on each other; not ankylosed, as in Ophiuridæ. 2nd. Inter-vertebral longitudinal muscles, smaller than the corresponding set in Ophiuridæ. 3rd. Inter-ambulacral, longitudinal. 4th. Transverse bands from the ad-orally expanded sides of the vertebræ to the floor of the ambulacral groove, which they can narrow.

Scattered over the body, or about the mouth, are prehen-

* Possibly the fossils Protaster, Palaeodiscus, &c., may belong here.

sile organs (*pedicellariæ*). Each consists of a short pillar supporting two or three movable blades or valves, which are usually open, but can snap together like a crab's pincers; some have two narrow-pointed (p. forcipata), or two or three broad, overlapping blades (p. valvata), and they may be sessile, as in Llwydia. The mouth is central, contractile; the stomach is a sac with numerous (usually ten) lateral cœca, each of which is tied to the dorsal surface of the body cavity by a radial membranous fold, and consists of a stem giving off 30–50 short, side branches, each ending in 6–8 vesicles containing a yellow or brown bitter fluid (bile ?); two of these stretch into each arm. The oral part of the stomach may become everted as a sucking organ, paralysing its prey by some secretion. *Deslongchamps* saw five everted soft vesicles inverted into the mouth of a Mactra, which was being devoured. *McAndrew* saw a similar sac attached to the hinder end of a Littorina. There is no anus in Astropecten, Ctenodiscus, or Llwydia; in the others it is central, subcentral, or to the left of the madreporiform plate in an interbrachial pore. In Astropecten there are two non-ciliated inter-radial cœca opening dorsally into the stomach; these are absent in Llwydia, five in Archaster, five bifid ones in Culcita; they are supposed to be hepatic or renal, but contain neither uric acid nor ammonia. The nerve ring is broad and flat, and may possess ganglion cells. Each radial branch is covered by a layer of ganglion cells, and dilates to the middle of the ambulacral space, being sometimes gutter-shaped, the demi-canal being completed into a tube by fine cellular tissue on the dorsal side. At the end of each ambulacral row the nerve often leaves its groove, and gives off one twig, ending in a gangliform swelling beneath the eye, and another to an extensile, ciliated feeler (*Greef*). The eyes are near the ends of the rays, and consist of 80–200 small, conical, stalked pigment granules, with crystal rods (?) surrounded by gelatinous tissue, lying under a common cornea (?).

The ambulacral system has a thick-walled oral ring, smooth, ciliated within, and surrounded by circular fibres externally; the pedicelli are conical in the aproctous, cylindrical in the proctuchous forms. Each of the five Polian

vesicles may be simple or divided into 2–7 smaller vesicles (A. aurantiacus), whose ducts, however, unite, so that there are never more than five openings. Right and left of each vesicle opens one of the ten spherical, hollow, grape-like bodies appended to the canal (Otocysts of *Baur*, but more likely the homologues of the oral tentacles of Ophiuridæ). Respiratory organs may exist on the dorsal surface as rounded or conical foot-like skin-processes, communicating with the body cavity (skin gills). In Solaster, the sea-water can enter the body by inter-brachial cribriform plates, pierced by the ducts of the genital glands.

The vascular system has its two rings and heart; when there are several sand canals, there are as many hearts, and the septum containing the heart is double the size of any of the other radial mesenteries. The anal ring is wide, pierces all the septa, and receives a genital vein on each side of each partition. The oral ring is narrower, more muscular, and lies under the nerve, and over the water-vascular ring. Under each angle of the mouth a vessel passes to each arm, and five branches are distributed to the stomach. The blood in the oral ring is yellow-brown, in the anal whitish.

Genital glands, each consisting of one (Ctenodiscus) or many grape-like masses, lie in pairs on both sides of the septa, even to the tip of the arm; in Astropecten these are numerous, and extend into the disc; in Llwydia, several thousand glomeruli are scattered along the whole arm. Each Astropecten may produce half a million eggs. The eggs in some are developed directly (Echinaster, Asteracanthion Mülleri; in Pteraster they develop in a dorsal brood sac, with a narrow neck placed between the paxillated membrane and the skeleton); but more commonly there is a larval stage, which may be possibly be one of three kinds:—1st. Bipinnaria—bilaterally symmetrical, skeletonless, flat, smaller at one end, and with lanceolate lappets along the margin. The rudimentary water-vascular rosette has swollen Müllerian appendages, and the stomach is formed in the protoplasm by invagination (Solaster, Asteracanthion). 2nd. Brachiolaria—with three warted arms anteriorly. 3rd. A worm-like larva of four metameroid segments, which, speedily losing its seg-

mentation, becomes pentagonal. Development proceeds as in pluteiform larvæ. In some, reproduction possibly occurs by fission, thus explaining the occurrence of heteractinism.

The following families are included :—

1. Asteracanthiidæ—proctuchous ; ambulacra four-rowed ; pedicellariæ stalked, straight, valvate, ex. Asteracanthion, the common orange starfish. 2. Astropectinidæ—ambulacra two-rowed ; back netted, paxillated ; pedicellariæ usually sessile ; anus none, except in Archaster ; body pentagonal (Ctenodiscus), or long-armed, with one ventral spine-bearing series of border plates (Llwydia), or with two (Astropecten, Archaster). 3. Oreastridæ—ambulacra two-rowed ; skin rough, pierced by numerous pores, flat on both sides (Astrogonium), or convex dorsally, often with large coarse eminences (Oreaster, Asteropsis). Echinaster has long conical or cylindrical arms, with numerous pores ; Cribrella, also long-armed, has few pores in the naked interspaces of the netted skin ; Solaster has ten or more paxillated arms, and many pores ; Chaetaster is clothed with bristles, Ophidiaster with granulated plates. 4. Asterinidæ—ambulacra as in last ; body discoidal or pyramidal, sharp-edged ; skeleton of imbricate segments ; dorsal wart single, rarely double, ex. Asterina, Palmipes ; Culcita is thick, with a leathery surface ; Pteraster has five short thick arms.

CHAPTER XXI.

CLASS 2. ECHINOIDEA (*Agassiz*).

GLOBULAR, oval, discoid, or heart-shaped forms ; brown, orange, red, or green in colour ; with a perisome (corona) of dermal, spine-clad, 4–6-angled, calcareous plates, arranged in usually twenty meridional rows, each of many (5–20) plates passing from pole to pole. The plates are deposits of calcium carbonate, and sulphate and a few other salts, in a basis of nucleated

connective tissue, whose fibres cross and unite at angles of about 120°–60°–90°. Usually the interstices are filled with protoplasm, in which resides the power of repair after injury. In dried perisomes the organic matter is about 9 per cent. The plates may be flexible (Astropyga), or rigid, and unite either by sutures filled by an organic cement soluble in alkaline carbonates, and ankylosing as age advances; or they may be separated from each other by a soft area (Asthenosoma). Before uniting, the plates grow as the body enlarges, by additions to their edges. The rows of plates are in pairs, five of which are pierced with holes for the ambulacral feet, and five are inter-ambulacral, each of two rows of imperforate plates. Both series of plates are beset with tubercles (spine-warts) for the articulations of the spine, in transverse rows, and varying in size; for as there are large, medium, and small spines, so there are primary, secondary, and miliary warts. The first set have often an apical depression for the round ligament of the spine, and a granular "spine-ring" around the base, girdled by smaller warts.

These plates, though apparently simple in the adult, are compound in most of the regular Echinoidea, and each consists of an ad- and an ab-oral entire plate (stretching from interambulacrum to the median suture of the ambulacrum), and one, two, or three intermediate half plates. At first they are all entire, but the rapid growth of the ab- and ad-oral plates causes the others to become triangular with the apex inwards. At first the pore-pairs are in a slightly convex arc near the margin; but as the test grows, the ad-oral pair are moved inwards, and downwards, and the ab-oral similarly, but more slightly, affected. Thus the arcs of pores in the adult, if counted from below upwards, commence with the second pair of a plate, and end with the first pair of the

plate above. As new plates are added at the vertex, pressure increases downwards, and resistance is afforded by the calcareous arches (auricles) to which the jaws are attached, and which extend over the ambulacral, as well as the interambulacral areas. Thus all the peristomial plates fuse as a solid ring round the buccal membrane. In Cidaridæ alone all the primary ambulacral plates are entire, and the sutures between them never become effaced by coalescence, and as the bases of the auricles are interambulacral, no opposition is offered to the downward motion of the ambulacral plates, which, being pushed over the buccal membrane, form a set of overlapping laminæ.

Around the anus is an apical circlet of five pentagonal shields (genital plates (Fig. 20, *c*), large and stellate in Astropyga), each pierced by a genital duct; with one of these the madreporiform plate is confluent, giving it a swollen, rough appearance. Outside and between these genital plates are five smaller, heart-shaped, ocular plates (Fig. 20, *d*), each at the end of the ambulacral radius, and bearing on its surface a red, cellular, photoscopic eye, with no refracting media, but with the last twig of the radial nerve ending in it. The genital plates are in two pairs in front and behind, and one posterior azygous plate.

Fig. 20.

Abactinal apparatus of Echinus; *a*, ambulacral plates; *b*, interambulacral plates.

In Spatangidæ, the place of this latter is taken by the madreporic plate, which, never separated by a suture from the right anterior genital plate, sometimes (Meoma, Brissopsis) spreads more or less over it, or even (Schizaster) occupies it to such an extent that both genital pore and gland have disappeared. Further extension of the madreporic area causes obsolescence of the left

anterior, or even of this and the right and left posterior as well (Abatus, Palæostoma). In Rotula, the madreporic plate is fused with all the united genital plates. Exceptionally it may unite with an ocular. The oral opening is larger than the apical, and the auricles project into the cavity around its border to support the dentary apparatus. In discoidal forms, pillars and processes along the ambulacra support the surface of the shell.

The surface spines are movable, and vary in length from 2½ times the diameter of the corona to a few lines, and from thick clubbed forms to fine hairs. They may be smooth, granular, ribbed, or verticillate. When young, they are covered by cilia, and on section show concentric laminæ of regularly netted, calcified tissue,* with meshes filled with protoplasm. The proximal end of each spine has a socket for the spine-wart. The largest have a round inter-articular ligament from the summit-pit of the wart to the bottom of the socket. Each spine joint is surrounded by a capsular ligament from the edge of the socket to the spine ring, outside which is a layer of longitudinal muscular fibres (*motores aculei*) capable of moving the spine. These are covered by ciliated epithelium and pigment cells. These rays are rather support- than locomotory-organs.

Among the spines in Spatangidæ are linear areas covered with fine, ciliated, clubbed bristles, with a calcareous axis (semitæ or fasciolæ). These may surround all (s. peripetalæ)

* *Mackintosh* has shown that the pattern of the network is generically and possibly specifically characteristic. As the spines of some Diadematidæ produce stinging sensations, possibly the protoplasm contains cnidæ (*Wright*).

or one of the ambulacral areas (s. internæ); or may surround the body equatorially (s. marginales); or may divide the sides uniting with the marginal semitæ (s. laterales); or may lie in front of, or around, the anus (s. sub-anales). Around the mouth is a buccal membrane bearing pedicellariæ (modified spines, *Troschel*), usually with three valves, and having a calcareous, netted axis in a soft, mucous tissue, and with simple muscle bundles uniting the branches. These may be:—1. P. globiferæ—with a solid stiff axis and a globular head like a closed three-leafed bud. 2. P. stereophyllæ—with a hollow axis and a round, calcareous head. 3. P. tridentes—shorter, with a hollow axis, and serrated arms with incurved points. 4. P. ophiocephalæ—with a longer pillar, and leaf-like limbs.

The ambulacral system consists of a circum-oral ring, five pedunculated Polian vesicles, cavernous in structure, with netted, unstriped fibres in the wall on the membrane over the dental apparatus, and five ambulacral canals, one between each row of holes, while proximal processes pass from the ambulacral canals to the buccal tentacles (*Perrier*). The tube-feet may be alike (ambulacra homœopoda), or dissimilar (a. heteropoda), and each has at its free end a radially plaited sucking membrane, under which is a calcareous, netted *rosette*, and sometimes a still deeper, calcareous *ring*. Arcuated and branched spicules often abound in the wall of the pedicelli. Heteropodal forms like Spatangus may have (α) simple feet, with no rosette; (β) sucking spiculigerous feet, with an entire or digitate margin; (γ) sensitive feet with broad pencil-like ends and flattened knobs, supported on fine, rod-like styles; (δ) gill-feet with pinnated margin; (ε) buccal pedicelli with no ring, and a rudimental rosette. The stone-canal from the madreporiform plate has its walls stiff with calcareous spicules, but

is never contractile. Sometimes the ambulacral radii extend from one pole to the other (amb. simplicia or perfecta), or they may be dorsal alone (a. interrupta, or if arranged in lobate rays, a. petaloidea). The pores are simple or slit-like (some Clypeastridæ, &c.) In Spatangoids, the hinder inter-ambulacral field has large symmetrically disposed spines (sternum). The mouth may be polar, eccentric, circular, or valvular, two-lipped (Spatangidæ), and is sometimes surrounded by a petaloid arrangement of pores (floscellus). The peristomial membrane may have thick lips and calcareous plates(Echinoneus minor). Radial (*decurtatores labiorum*) and circular muscular fibres are present in the lips. Teeth may be present, rudimentary (Galerites), or none (Spatangidæ, Echinoneus, Cassidulina). The peristomial edge of the corona is often notched for the gills when they exist.

The anus is round or oval, and may be polar in a granular plate (periproct, the morphological equivalent of the whole dorsal surface of Asterias) in the centre of the genital circlet. When eccentric, it may open on the vertical side of the perisome (*pleurocysta*), or on the ventral side (*catacysta*), near the mouth, midway between it and the margin, or at the margin (Echinarachnius).

The dental apparatus is conical, with its narrow end directed outwards, and its base inwards, and it can easily be examined in the common sea urchin; it is suspended by muscles and ligaments to the auricles, and consists of five wedge-shaped *jaws* arranged around the pharynx. The flat sides of each jaw are transversely striated and opposed to each other. Each jaw consists of two segments united by suture. These diverge at the base, and are separated by an interspace, arched over by an *inter-radial arch* (Ergänzung-

stücke, *Meyer*), each made of two segments (Epiphyses), uniting by a median suture. Between each jaw and its neighbour, along the base of the pyramid, lie flat *radial pieces* (rotula, Schaltstücke, *Meyer*), forming a fixed basis for the separate motions of the jaws. Parallel to, and deeper then these, are five radial, Y-shaped *manubria* (Gabel- or Bügelstücke) attached within to the middle notch at the central end of the radial pieces, externally projecting freely by their forked ends between the jaws; each of these is also double, consisting of an inner and outer segment, united by a suture. In the axis of each jaw, between its segments, is a long, curved tooth, whose tip projects as a hard, enamel-coated, chisel-like point, and the basal end is fibrous, asbestos-like. There are thus forty segments in this "lantern;" five teeth; five jaws, each of two segments; five radials; five inter-radials, each of two pieces; and five manubria, each likewise double. The muscles to move the apparatus are:—1. Five intermaxillary, transverse fibres to approximate the jaws from the opposed surfaces of each jaw to its neighbours (*Interpyramidales*). 2. Five intermanubrial clear bands, forming a pentagon on the base of the jaws, for approximating the manubria. 3. Five pair of *dilatatores orificii dentium*, which can also retract the whole apparatus, arising two from each auricle, and attached to lateral grooves at the apex of the jaws. 4. *Comminutores ciborum*, also five pairs arising from the interambulacral margin, and passing upwards and inwards, narrowing to the inter-radial arches. A fine muscle is described by *Valentin* at the base of each tooth, but I have not found it. From each inter-ambulacral space to the outer end of each manubrial fork stretches an oblique ligament, which has a few smooth muscular fibres in its origin: besides these ligamenta externa obliqua, there are ligamenta externa recta, thin vertical membranes from the auricles to the inner end of the manubrium. The dental apparatus in Cidaridæ differs from that of Echinus, above described, as the epiphyses do not unite mesially to form inter-radial arches, but are ankylosed to the radial pieces. In Laganum the jaws are unsymmetrical.

The pharynx is pentagonal, narrowing to the

œsophagus, supported by five tendons attached to the radial pieces, and has a muscular coat. There are small glandular cæca along the œsophageal wall. The intestine is long, once or twice coiled within the somatic cavity, and held in its place by fenestrated mesenteries from the wall of the ciliated perivisceral cavity. Cæca are present in some Clypeastridæ, projecting between the pillars of the shell. The end of the intestine (rectum) has firmer mesenteries than the middle. The intestinal wall consists of an outer serous ciliated layer, a middle muscular, and an inner also ciliated with a layer of brown or yellow (hepatic ?) cells.

The heart* is fusiform, in a common sheath with the stone-canal, having an outer ciliated, a middle spiral or reticular muscular (thick in Cidaris), and an inner tessellated epithelial layer. The circum-oral ring into which the heart opens sends radial vessels to the muscles of the jaws and to *one* side of the intestinal wall. Along the opposite side of the intestine there is a second vessel, the intestinal vein, receiving the blood from the wall of the intestine, and the chyle from the digested food. This vessel breaks up, as it approaches the perisome wall, into branches which ramify on the wall, where their contents become aerated. From hence the dark yellow blood is returned by fine branchial vessels to the circum-anal ring from which the heart arises. The heart current

* *Perrier* describes the heart as a gland, and denies the existence of any other ring but the water-vascular one. He describes the passage of a vessel from opposite the right anterior Polian sac to the intestine joining the intestinal vein, thus uniting the ambulacral and circulatory systems, a connexion also described as existing in Spatangus and Toxopneustes by *Hoffman*.

moves from anal to oral ring, and no part of the lining of this system is ciliated.

Respiration is thus superficial, but in some there are five peristomial, branched gills, with hollow stems communicating with the body cavity, into which they may admit the sea water; they are ciliated within and without, extra vascular, and sometimes spiculigerous.

The violet or green circum-oral nerve ring is close to the teeth, covered with ganglion cells: it is irregular in Spatangoids; in the others, it sends through each auricular loop an ambulacral nerve, or pair of nerves, which runs between the two series of ambulacra, and ends in the ocellus.* Two lateral threads pass to the intestine, and several to the jaw muscles. The ambulacral nerves thicken to the centre of their course. The sphaeridia of *Lovén*, which may be counted as sense organs, are globular or button-like bodies on stalks, placed along the ambulacral line and on the peristomial plates. They are absent in Cidaridæ, sunk in dome-like hollows in Clypeastridæ.†

The genital glands lie one in each inter-ambulacrum. The testes are white, the ovaries reddish or yellow, both lanceolate and plicated: they are four, and unsymmetrical in most of the eccentric forms. The ducts traverse the pores of the genital plates, and the products are slowly emptied. The eggs are small, 10–12 in each grape-like bundle of the ovary. Half-an-hour after impregnation, yelk rotation begins; in 3–4 hours fission occurs; and in eight hours each egg is

* The spines round the ocellus are called "eyelids."

† There may be one or two sphæridia in each peristomial plate. They move slowly in Brissopsis.

mulberry-like, while cilia appear in twelve hours. The larva is apple-shaped in three days, then becomes pyramidal, developing simple, calcareous rods within, and ciliated "epaulettes" on the surface (except in Spatangus, in which also the calcareous rods are fenestrated). The water-vascular rosette is developed as usual in the eight-armed larva, which soon begins to break up; its hinder end becomes absorbed, and the first trace of spines and pedicelli soon appear. Finally the larval skeleton is lost, and the adult form assumed.

Anochanus Sinensis is an aberrant form with spines, ambulacra, and pedicellariæ, but no genital glands, nor pores. It has an apical sac, in which are several young echinids in various stages of growth; possibly a case of metagenesis (*Grube*), or a concealed form of fission, or most probably a simple case of vivipareity.

They are divisible into two orders:—

1. Tessellata.—Palaeozoic—5–6 series of plates, some of which are hexagonal, in each inter-ambulacral space; mouth central, with a masticatory apparatus; spine-warts weak; anus dorsal; ambulacral plates may be in more than two-rows (Melonites), or two-rowed with imperforate spine-warts (Palæchinus), or perforate; possibly passage forms to the Cystidæ.

2. Euechinoidea—with two sets of ambulacral and two of inter-ambulacral plates alternating with each other. This order includes two sub-orders:—1. Endocyclica or Regularia—with central, or sub-central, round or 5–10 angled mouth, with five equal ambulacral fields. This includes six families:—1. Cidaridæ—with perforate, smooth tubercles (spine-warts); no peristomial notches in the corona, nor perforated tubercles on the narrow ambulacral plates. The peristomial membrane has scales and ambulacral feet. There are

no circum-oral gills, and the spines are large and clavate; anal plates ten. 2. Salenidæ—extinct, (except S. rarispina), jurassic and cretaceous forms with eleven anal plates. 3. Diadematidæ—perforated, crenulated tubercles; spines usually hollow; the ambulacral area with perforate tubercles; peristome with notches. 4. Arbaciidæ—tubercles smooth, imperforate; no sutural pores; periproct closed by four plates. 5. Echinidæ—spine-warts and sutural pores as last; periproct of many plates; body circular or pentagonal; pores in three or four pairs on each plate; including Temnopleurinæ, with oral notches shallow, and no ocular plate reaching the periproct; and Triplechinidæ, with two ocular plates reaching the periproct, and the oral notches deeper than broad. 6. Echinometridæ—pores in five or six pairs; body elliptical; including Heterocentrotus, with club-like spines; Colobocentrotus, with the dorsum of the test covered with pavement-like spines, &c.

Sub-order 2. Exocyclica—the anus not in the centre of the apical apparatus: there are five families:—1. Galeritidæ—genital pores four; ambulacra ending in an apical point; including the toothless Echinoneus. 2. Dysasteridæ—Mesozoic, with the ambulacra converging to two apical points; three anteriorly forming a trivium; with three ocular and four genital plates, two posteriorly (bivium), with two ocular and no genital plate. 3. Clypeastridæ—ambulacra petaloid, often not distinct towards the margin; mouth central, with teeth; anus inferior; spine-warts notched and perforate; shell wall with duplicatures, pillars, and chambers; madreporiform plate central; the shell may be inflated and the jaws moveable on the auricles (Clypeastrinæ), or fastened thereto, and the shell flat (Laganinæ); the shell may be lobed, or pierced by large holes, and the ambulacral rows branched (Melittinæ). 4. Cassidulinidæ—mostly cretaceous and eocene; toothless, with petaloid ambulacra, imperforate and entire spine-warts; genital pores five; anus posterior or inferior. 5. Spatangidæ—heart-shaped, toothless, with an anterior reniform mouth, and interrupted ambulacra; bivium embracing a sternal field; semitæ may be entopetalar and sub-anal, not peripetalous (Echinocardium, Lovénia), or with a peripetalous area (Breynia);

entopetalous, peripetalous, and lateral semitæ wanting (Hemipatagus, without, and Spatangus with a closed anal semita). The peripetalous may be present with (Agassizia, Schizaster, &c.) or without a lateral semita (Brissus). In Leskea, the mouth resembles that of a Cystidean.

CHAPTER XXII.

CLASS 3. HOLOTHURIDA.

SEA cucumbers, dark brown to purple-red, varying from ½″–10″ long. Shell-less, elongated Echinoderms, with an epidermis not divided into cell-areas, and a dermis with many calcareous, specifically characteristic spicules; sometimes forming a scaly layer (Actinopyga squamata, Cuvieria); rarely absent (Thyonidium, &c.) Beneath this is an elastic connective layer, and a lamina of circular, muscular fibres imbedded in protoplasm, and forming a continuous sac; some of these fibres are continued into the mesenteries. Five deeper meridional bands of longitudinal fibres extend from mouth to anus, sending fibres into the tentacles. These may, on irritation, act so forcibly as to expel the viscera through the orifices, or to rupture the surface. Within these there are often calcareous scales and a ciliated lining.

The mouth is polar, toothless, surrounded by 10–20 plumose, simple or tasseled, prehensile, ciliated, sensitive tentacles (altered ambulacra); these may be equal or unequal, sometimes margined with little suckers (Synapta digitata and inhærens). The bases of these contain cæcal branches of the water-vascular

system. The anus has a round or pentagonal muscular sphincter, into whose edges the longitudinal body muscles are inserted. The pharynx is oval and glandular, separated from the stomach by a sphincter, surrounded at its origin by a moveable ring of 10, 12, or 15 plates, five of which are usually notched or pierced (Synapta), *radial*, and five are *inter-radial;* these represent the auricles of Echini. Five muscular bands unite these plates, and 10–12 pyramidal bands arise by their apices therefrom, and have their broad bases inserted into the pharyngeal wall: they can draw forwards the pharynx. The digestive canal is straight or curved, attached by often uninterrupted mesenteries. It sometimes ends in a cloaca directly above the anus. In the intestine there may be 2–4 longitudinal folds, possibly the extension of an absorbing apparatus. The alimentary canal contains diatoms, foraminifers, and sand.

The dermis acts as a respiratory organ, so do the remarkable tree-like, long branching organs, ciliated within and without, which arise from the cloaca, and stretch in the body cavity towards the mouth. Water enters them from the cloaca, and passes into the body cavity from them by holes in the tips of the branches. These water-lungs are homologous to the inter-radial cæca of Asteriadæ. Water enters in other forms by inter-tentacular pores. The tree-like organs vary in size; in some forms they are joined to the wall of the somatic cavity by threads, and even where the trees are absent (Synapta), these threads remain appended to the mesenteries with attached to their inner ends ciliated, slipper-like, or cornucopiæ-like organs, and communicating with the pseud-hæmal system. Rarely

are the trees singly branched (Echinocucumis). The pseud-hæmal ring sends off two pulsating vessels along the intestinal canal, dorsal and ventral, connected by reticular vessels; branches pass from one of these to the right water-lung, and in Aspidochirotæ a plexus of branches of the dorsal vessel is related to the left respiratory tree. The ventral vessel in Chirodota displays numerous varicosities. The yellow or brown blood is coagulable, and contains colourless corpuscles and amæboid mucous cells.

The intestine is lined by yellow cells, secreting a bitter fluid (bile ?). Solid fibres or thread-like tubes open into the cloaca (Cuvierian organs). They may be as long as the respiratory tree, and cæcal (30, Bohadschia), or small (Holothuria), filiform, grape-like, and very numerous; or bundles of spindle-shaped sacs (Mülleria, Pentacta), filled with fine vesicles. They are absent in Apneumona, &c. The body surface often secretes slime from its dermal follicles. The nerve-ring is often red, thicker than the radial branches, and lies in front of the calcareous plates and water-vascular ring; it sends off tentacular and ambulacral nerves, the latter sometimes trifid, through holes in the radial plates. Inter-tentacular pigment flecks in Synapta are described as ocelli, but no nerves have been traced satisfactorily into them. Synapta Beselii has small vesicles placed around the mouth where the radial nerves pass through the holes in the oral plates, possibly otocysts. The spicules in the tentacles usually differ from those of the body.

The ambulacral oral circle may have 1–100 (Cladolabes) Polian vesicles. The stone-canal is short, usually single, but may be multiple (Synapta serpentina), or branched (S. Beselii). It hangs free from the body cavity, often holding a wide, calcareous, spiculigerous sac with a sieve-like wall at its end, representing the madreporiform plate. This canal has often a

stiff, inflexible wall, composed of an outer and inner porous, and a middle spiculigerous membrane, and the cavity may be labyrinthine. In the Dipneumona, five branches pass to the calcareous ring, on the inner side of which they divide into branches to each ambulacral foot and tentacle. The pedicelli are conical, without, or cylindrical, with a sucking disc, sometimes irregularly scattered (sporadipoda), or in 2–5 rows (stichopoda), making a discriminable dorsal (bivial) and ventral (trivial) surface. The abdominal feet may differ from the dorsal (heteropoda tristicha); rarely the bivial fail altogether, and the ventral are limited to a few series on the abdomen (Psolus). The pedicelli have rudimental rosette plates; some non-retractile feet have calcareous supports in their side walls. Progression is by creeping; the actinoid Minyas walks on its tentacles, and some Synaptæ can swim.

Except in Synapta and Molpadia, the sexes are separate, as in the other Echinoderms. The sex-organs are not radial, but single ramose, attached to one or both sides of the dorsal mesentery. There is a common duct opening dorsally beneath the mouth. Only when the products are ripe can the testis and ovary be distinguished from one another. The zoosperms are pin-shaped; the ovum has a firm, radially-striated envelope, with a micropyle; Synapta vivipara is viviparous; Holothuria tremula develops directly; the others mostly undergo metamorphoses. From the egg escapes a bilaterally symmetrical planula, which develops an anus and a digestive canal. The cilia limit themselves to two girdles, and the form is then called Auricularia, with short sac-like processes, sometimes spicules, but no calcareous skeleton. In moving,

this rotates on its long axis, and soon develops a mouth, stomach, and anus, and Müllerian swellings, as well as a calcigerous gland posteriorly. This body then becomes barrel-shaped, opaque; its mouth disappears, and it becomes a "Pupa;" draws in its side lobes; the stone-canal sinks into the body, the cilia disappear, the tentacles and mouth form, and the animal assumes its mature shape. The power of reproducing lost parts is great.

As commensal entozoa in Holothurids have been found fishes (Fierasfer), crustacea (Pinnotheres), and gasteropods (Entoconcha mirabilis, whose eggs and embryos have been found in the ovaries of Holothuria), Helicosepina, a shell-less gasteropod, has been found in Synapta digitata. Eulima, Montacuta, and Stylifer, are found outside or inside Echinoids, Starfishes, or Holothurids.

The class is divided into three orders, containing about 270 species.

1. Apneumona (*Brandt*)—with no tree-like water-lungs nor Cuvierian organs; anus and mouth polar; ambulacral canals 5; hermaphrodite. Two families are included:—1. Synaptidæ—footless; in Synapta the skin bristles with anchor-like spicules, and millet-seed plates in the intervals, especially along the muscle-bands. Some species (S. inhærens) have true nettle-cells; others in which these cells have not yet been demonstrated, have a stinging power. Anapta has no anchors, but biscuit-shaped spines. Chirodota has calcareous wheels, with 6–16 spokes, which may be mounted on an axis (Myriotrochus). Eupyrgus has conical perforated plates and fifteen undivided tentacles. 2. Oncinolabidæ—ambulacra present; tentacles thread-like; skin with barbed spicules. Echinosoma has no ampulla to the tentacles; no feet, and rudimentary gills.

2. Tetrapneumona (*Schmarda*)—with four gill-cæca at the end of the intestine; mouth and anus at the same end, each

surrounded by a ring of ten plates, and both at the narrow end of a flask-like body; ambulacral canals in five double rows, each with two sets of little feet and two Polian vesicles; tentacles 10; the single sex-opening is at the top of the neck. This includes one species Rhopalodina lageniformis from Congo.

3. Dipneumona, Pneumonophora (*Brandt*) have two tree-like water-lungs and Cuvierian organs; the mouth and anus are polar, and the ambulacral rows are never double. This includes three families:—1. Liodermatidæ—footless, with twelve shield-like tentacles (Liosoma), or ten single cylindrical (Haplodactylus) or branched tentacles (Molpadia). In this genus, the cæcal sacs of the water-vascular system end in the skin, but are not prolonged into pedicelli. 2. Dendrochirotæ—tentacles branched, unequal; they may be sporadipodous, homœpodal, with ten (Thyone), twelve (Phyllophorus), or fifteen retractile tentacles (Orcula); rarely stiff (Sclerodactyla) or heteropodal, with twenty tentacles (Cladolabes); or the feet may be stichopodous in five rows, with twenty (Thyonidium) or ten tentacles. The feet in each row are uniserial, retractile (Ochnus), or non-retractile (Perlinus); or they may be in 2–6 series with equal (Cladodactylus) or unequal (Dactylota); or they may be tristichous (Psolus, Cuvieria). 3. Aspidochirotæ—tentacles shield-like; Cuvierian organ cæcal, well developed; feet pentastichous (Aspidochir) or heteropodal; those of the trivium suctorial at the end; those of the bivium conical (Stichopus), or sporadipodal, homœopodal (Sporadipus), or heteropodal; abdomen swollen, as in Trepang (the edible Chinese form), or flat, with a round (Holothuria), five-angled, toothless (Bohadschia), or five-toothed anus (Actinopyga).

CHAPTER XXIII.

SUB-KINGDOM 5.—VERMES.

BILATERALLY symmetrical, usually soft, elongate, often parasitic animals, of one or many metameres; with differentiated dorsal and ventral surfaces, but never with jointed limbs. The nervous system generally consists of one or two pharyngeal ganglia, and sometimes an abdominal nerve-cord. Sense-organs are rarely complex. Sexual reproduction occurs in every species; metagenesis is common, but fission or gemmation is rare. The ova are holoblastic, and the embryo has rarely a primitive streak (except in leeches). The epidermis may be cellular or protoplasmic, ciliated at first, but the cilia are in general early shed, and a deeper layer exposed, with bristles, hooks, scales, &c. The dermis is fibrous or connective. The subjacent muscular layer is either united to the body parenchyma, or separated from the viscera by a body cavity. There is a tubular water-vascular system opening externally, and often also into the body cavity; this may be excretory, as *Lieberkühn* found guanin in its contents, but it is never connected with locomotion. The mouth is at the end foremost in progression, which may be specialized as a head. The anus is farther back, or none. The higher forms have a closed vascular system, but no pulsating sacs.

This polymorphic sub-kingdom may be divided into two provinces, including thirteen classes.*

* Some unite Turbellaria, Cotylidæ, Nematelmia, and Acanthocephala under the name Scolecida. Gephyrea has been joined to Echinodermata, to Scolecida, or Annelida. Hirudinea has been placed beside or under

PROVINCE 1. ARCHÆOSTOMATA* (*Huxley*).

CLASS 1. TURBELLARIA (*Ehrenberg*).—Unjointed, rarely parasitic, ciliated, leaf- or ribbon-like worms, rarely with chitinous processes or bristles (not arising in follicles), or circlets of stronger cilia (Dinophilus). The integument consists of cells or of undivided protoplasm, containing, in the aquatic forms, nettle-cells scattered or clustered ; sometimes rod- or spindle-like bodies, with (Meckelia) or without appended threads may exist in capsules, like those of the true nettle-cells (absent in Geoplana, *Schultze*).

The integument may also contain chlorophyll (Vortex viridis, Convoluta Schultzii) or calcareous concretions (Sidonia elegans). The component plastides are best seen in land planarians, where the glandular elements are divided into superficial and deep. The sub-cutaneous muscular layer consists of usually three laminæ, an outer circular, well marked in Bipalium and Dendrocœlum, often undifferentiated in others, a middle, longitudinal (the strongest), and an inner circular.† The fibres in most are but spindle-cells loosely scattered in a net-work of connective tissue (except in Nemertinea).

Cotylidæ, or united to Chætopoda to form a group Annelida. Rotatoria is placed by many among the Arthropods near Crustacea. Bryozoa and Tunicata are usually and naturally united to Brachiopoda to form a sub-division Molluscoida, but as the Mollusca proper are only an extreme of specialization of this sub-division of Vermes, it would be still more natural to add them all together in the one sub-kingdom. However, as for convenience we retain the specialized group separately, it is to a large extent arbitrary where the line of demarcation is drawn ; so, though many eminent zoologists, as *Lankester*, prefer to retain the Tunicates, &c., with the Molluscoids, I have followed *Gegenbaur* in my classification.

* These characters (p. 47), being primary embryonic ones, should override the sub-kingdom characters here adopted ; but in the present condition of our knowledge, we can scarcely apply them to all the included forms.

† Among Nemerteans, these vary in their arrangement.

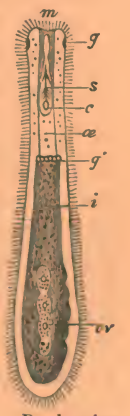
The persistent embryonic mouth (homologous with the anus of some higher forms) is either anterior or abdominal, surrounded by radiating and sometimes circular muscle-fibres, and may be trumpet-like, plicated in some land forms. The part of the body in front of it is the *prostomium*. The pharynx is muscular (except in Schizostomum), and may be protrusible, with one-celled glands opening therein (Vortex, Derostomum), or with 2–3-celled (salivary) glands in some Rhabdocœla. Short, retractile, marginal, or dorsal tentacles may project (Proceros, Stylochus, &c.), or the skin of the front of the body may be lengthened and crumpled as pseudo-tentaculæ. In Nemertinea, a special proboscis exists in front of the mouth, an eversible muscular sac (Fig. 21, *s*) sometimes as long as the body, or longer; when retracted, it lies, convoluted, in a sheath or short sac, surrounded by a corpuscular fluid, under the dorsal integument and over the intestine; when protruded (by the action of the circular fibres in its wall), its apex is, in Nemertinea enopla, armed with a strong spine, often surrounded by smaller ones; a saccular poison gland (*c*), placed near the end of the cavity of the protruded proboscis, opens by a duct at the base of the chief spine; a retractor muscle arising from the body-wall traverses the axis of the proboscis to its tip, and can draw it in. Some Nemerteans (N. anopla) have no spines.

The stomach may be a simple pouch (Rhabdocœla), with (Microstomidæ, Nemertinea) or without an anus, or it may give off branching, coloured cæca, or the tube may begin to branch at the pharynx; in these cases it is aproctous (Dendrocœla). Some Nemerteans have a body cavity around the stomach (which is held

in place by thread-like, muscular mesenteries); but in most, the digestive cavity is an excavation in the body parenchyma, lined by epithelium, and without or with (Geoplana), a muscular coat for its chief branches. The whole digestive tract is ciliated in Nemerteans.

The simplest forms have no circulatory system. Nemerteans possess two lateral, pulsating vessels, which dilate as they pass backwards, and unite in front. Each of these sends a branch round the front of the nerve ganglion, which unites with its fellow to form a third medio-dorsal tube. These may give off no branches (Tetrastemma), or may be joined by transverse canals (indicating a hidden metameric structure?). The blood is white or reddish. There are no respiratory organs.* The water-vascular system exists as two long, ciliated, often branched, separate or connected lateral tubes, reticulated within, opening by a posterior terminal, or by a lateral pore, rarely into the mouth (Enterostomum Fingalianum, and Mesostomum).

Fig. 21.



Prorhynchus fluviatilis; *m*, mouth; *g*, ciliated groove; *s*, spine; *c*, sac of proboscis; *g'*, gastric glands; *æ*, œsophagus; *i*, intestine; *ov*, ovary.

There are two, often reddish, bi-lobed nerve ganglia, one at each side of the pharynx, rarely far apart (Valencinia); united by a commissure above that tube. From this two lateral nerves pass backward (weak in Dendrocœla, stronger in Rhabdocœla), extending the whole length of the body in Nemertinea, and in the larva of Prosorhochmus, each ending behind in a

* The arches beside the pharynx form in Lineus a rete mirabile, from which it is only a step to the branchial organ of Balanoglossus.

gangliform swelling. In many Dendrocœlans, the feeble nervous system has no detectible ganglion cells, and lies within the primitive vascular canals (water-vascular system). Reddish or black photoscopic eyes exist in many, either few on the neck or many marginal and clustered; refracting bodies are added in Vortex, Mesostomum, &c., and rod-like processes in Geodesmus. In eyeless Rhabdocœla, and a few Nemerteans, there is sometimes, close to the ganglion, a single clear ear-vesicle ciliated within, containing a spherical otolith. This rarely co-exists with ocelli (Œrstedtia pallida, Monocelis anguilla).

Rod-like bodies lying on the ganglion in a few forms may be touch-organs. In Nemerteans, there is on each side of the front end of the body one or two ciliated grooves (Fig. 21, *g*), which may be shallow, conical, or with margins capable of closure, on whose floor is a ganglion clothed by ciliated protoplasm. The roots of these ganglia arise from the side (Nemertes), back (Cerebratulus), or front (Polia humilis) of the pharyngeal nerve centre, or from the lateral nerve cords (P. bembix). These are regarded as smell-, taste-, or touch-organs, or as the mouths of excretory ducts (?) (*Van Beneden*). Traces of similar grooves exist in Microstomidæ, Polygordius, &c. They are absent in Cephalothrix, &c. In Carinella annulata, a frill exists representing the upper lip of the cephalic fissure. At the ends of the grooves are two lateral sacs, with a funnel-like ciliated duct. The sac wall has a streak of finely granular ciliated cells. In Bipalium, the head possesses rows of papillæ and ciliated pits.

Reproduction occurs rarely by transverse fission (Microstomum), freely by artificial division, by continuous gemmation producing a tape-worm-like form (Derostomum catenula), but commonly by ova. Most are hermaphrodite, often self-impregnating, with a common (most Rhabdocœla) or separate sex-openings

(Dendrocœla). The female organs consist of—1st, a germ-gland secreting the central part of the egg; 2nd, one or two yelk-glands secreting a cellular material, not homologous with true yelk, which contributes chiefly to the formation of the embryo. These may open separately or in common into the oviduct, which is at one part dilated into a uterus, where the eggs accumulate and begin to develop. To this is added a shell-secreting gland and an external duct or vagina, often with a dilatation for the reception of the semen (spermatheca). The male organs in Rhabdocœla consist of a pair of pouch-like testes, with ducts opening in seminal vesicles, and ending in a perforate cirrus or penis, armed with recurved hooks, and, when retracted, contained in a sac. In Dendrocœla, many vesicular testes exist scattered through the body, sometimes in pairs (Bipalium). In Convoluta, some individuals have developed male and rudimental female organs, and others the reverse, leading us to the diœcious forms (Microstomidæ, Acmostomum dioicum, Nemertinea, Planaria dioica). The sex-organs of Nemerteans are simple follicles between the intestinal cæca, opening laterally by pores above the lateral nerves. The spermatozoa are rod-like. The ova are rapidly developed; sometimes several embryos arise from one egg. In some cases (Borlasia), the stomach cavity appears to form by invagination (*Hubrecht*). In other Nemerteans, the embryo forms as a vesicle of one layer (blastula), which becomes ciliated, free, and then by invagination becomes a gastrula.* In Nemertinea, the soft-shelled eggs are

* The blastula stage precedes the perfect triploblastic planula stage in Ascidians, Amphioxus, &c., as well as in Nemerteans (*Salensky*). *Knapper* describes Planaria as a true diblastula.

imbedded in slime, and early develop a helmet-like larva (pilidium), with an apical flagellum, ciliated sides, and a simple, inferior, alimentary canal. The history of this is comparable with that of the Echinodermal pluteus, as only the digestive canal and the blastema around it develop into the perfect form; the rest is only provisional. Some larvæ shed only their ciliated skin.

This class contains the following orders :—

1. Dendrocœla (*Ehrenberg*).—Digestive cavity tree-like, aproctous; pharynx protrusible; body broad and flat; sex-openings double; mostly marine; a few freshwater and land forms. This contains two sub-orders :—1. Acephala—development often with metamorphosis; anterior end not specialized into a head; including four families :—1. Aceridæ—with no tentacles; eyeless (Polycladus, Typhlolepta), or with 2 (Dicelis), 3 (Tricelis), 4 (Tetracelis), or many eyes (Polycelis,* Leptoplana), in which the two vasa differentia are united by a common duct. 2. Pseudoceridæ—with pseudo-tentaculæ; the back is smooth (Eurylepta) or papillose (Thysanozoon); the latter has a double penis. 3. Prostheceridæ—tentacles true, anterior; the pharynx is entire (Prostheceraeus, Homaloceraeus, Schmardea), or divided along its protrusible margin (Phagocata). 4. Notoceridæ—tentacles on back of neck; eyes none (Planacera), or at the base (Stylochus), or at the point of the tentacles (Imogene). Trachyplana has hyaline tentacles.

Sub-order 2. Cephalota—prostomium differentiated; development without metamorphosis, including two families. 5. Carenota—head distinct, hammer-like (Bipalium, a land form from Ceylon and India), four (Cephalocarena), or three-sided (Goniocarena), with two tentacles (Carenoceraeus). Polycladus is eyeless. 6. Planariidæ—head not very distinct nor tentaculate, often with processes; mouth medio-ventral. Planaria has two eyes; Anocelis has none; Dendrocœlum has

* These genera have simple development.

auricular processes on the head; Rhynchodesmus and Geodesmus are terrestrial; Procotyla has a cephalic, and Bdellura a caudal sucking disc.

Order 2. Rhabdocœla.—Intestine a simple pouch; pharynx not protrusible in some; usually one sex-opening; testes pouch-like; many are freshwater, others marine. This order includes five families:—1. Microstomidæ—proctuchous; mouth small, round, terminal in Proporus (eyes none), and Disorus (eyes six), sub-terminal in Vorticerus; it is slit-like, sub-terminal in Microstomum, terminal in Schizoprora. 2. Pharyngeidæ—pharynx protrusible, somewhat urceolate, cylindrical, or conical; mouth terminal (Acmostomum), or sub-terminal (Vortex); it may be a transverse (Stenostomum), or a longitudinal slit (Derostomum); or central, with a cylindrical (Mesopharynx), or funnel-shaped pharynx (Chonostomum), or post-central, with one (Monocelis), two (Diotis), or no otolith (Opistomum). 3. Apharyngeidæ—pharynx not protrusible; mouth circular, sub-terminal (Strongoylstomum), or medio-ventral; eyes two (Mesostomum), or none (Typhloplana); or the mouth may be slit-like, transverse, behind the otolith (Convoluta), or longitudinal, terminal (Telostomum), or sub-terminal; eyes two (Macrostomum).* 4. Rhynchoprobolidæ—having a terminal proboscis, and a sub-terminal (Prostomum), or central, round mouth (Rhynchoprobolus). 5. Catenulidæ—several individuals united in a longitudinal stock by continuous budding; head distinct; European and South African forms. 6. Dinophilidæ—form a link to the next order, as they have a body cavity in which lies the proctuchous stomach. They also have a number of girdles of long cilia.

Order 3. Nemertidea (*Œrsted*, Rhynchocœla, *Schultze*)—long, worm-like, mostly marine, proctuchous, diœcious,† proboscis-bearing‡ Turbellarians, with contractile, brittle, sometimes transversely striped bodies (rudimental annulation), and numerous dermal muciparous glands, with sometimes a fourth muscular lamina (of internal longitudinal fibres,

* Yelk and germ-glands united; separate in Orthostomum.

† Except Borlasia hermaphroditica.

‡ Proboscis small in Prorhynchus and in Polia involuta.

Cerebratulus). The large nerve ganglia are joined by a double commissure, and the lateral cords are thick. The eyes are seldom lens-bearing (Polia coronata, Nemertes Antonina, Tetrastemma); sometimes two long series of pigment specks and nerves exist, as in Borlasia splendens. There is usually a closed perivisceral cavity, except in the few fresh-water forms. A separate circulatory system exists, with currents, often oscillating to and fro. The straight intestine has lateral cæca attached to the body wall by filamentary mesenteries, which also support the sexual pouches. When the latter are distended with eggs, they displace the other viscera. Tetrastemma obscurum and Prosorhochmus Claparedii are viviparous. They are united to the last order by Microstomidæ and Dinophilidæ, and to Trematoda by Prorhynchus. In some there is a larval stage (Pilidium—see above, p. 160*).

This order is divisible into two sub-orders :—1. Arhagea—with rudimental or no cephalic grooves (p. 158). This includes two families :—1. Borlasidæ—with a simple, un-lobed head, and two (Cephalothrix), four (Œrstedia), or many eyes (Ommatoplea, Polystemma), or eyeless, with a terminal (Borlasia) or sub-terminal proboscis (Valencinia). Prorhynchus has a very short proboscis. 2. Chlamidocephalidæ—head two-lobed, divided by a shallow or deep notch (Colpocephalus, Chlamidocephalus). The lobes may be long, again lobed (Lobilabrum).

Sub-order 2. Rhagophora—with head grooves, including three families. 3. Monorhagea—with one transverse groove, eyeless (Tubulanus), or with two rows of eyes (Micrura†), or

* In the larvæ of Echinodermata and Vermes, three types may be discriminated—1st, that in which a ciliary girdle divides the surface into an anal and an oral field (Bryozoa, Gephyrea, Holothuria, Echinoidea); 2nd, that in which two ciliary zones divide the surface into three regions, an oral, an anal, and a terminal (Asteriadæ, some Chaetopoda, Fig. 22, B); 3rd, that in which one ciliary course separates the single oro-anal field from an imperforate terminal one (Pilidium, Chaetopoda, Rotatoria, Fig. 22, C). The second and third are derived from the first.

† Micrura has a terminal, attenuated, and contractile style, a prolongation of the body wall, ciliated externally.

a semicircle of many eyes (Hemicyclia). 4. Dirhagea—with two grooves, which may be very long (Nemertes, Lineus), or short, with four (Tetrastemma*), or no eyes (Meckelia†). 5. Tetrarhagea—with four grooves (which are converging x-like (Ophiocephalus), or short, transverse (Loxorrhochma). *Schultze* and *McIntosh* divide Nemerteans into two sub-orders:—1. Anopla—with no style in the proboscis; the nerve trunk placed between the muscular layers; the mouth opening between the commissures; development with metamorphosis. This includes:—1. Lineidæ—with elongated ganglia; the body muscles externally longitudinal, mesially circular, and internally longitudinal: the proboscis has no internal, longitudinal nor reticular layers, but consists of five coats, external elastic, external longitudinal, circular, basement, and glandular laminæ; the vessels in the œsophageal wall form a rete mirabile; the head fissures are deep; a separate longitudinal band is detached from the investing stratum of longitudinal fibres. Lineus has a long, slit-like mouth and variable eyes; Borlasia a slender proboscis; Cerebratulus a flattened body, thinning to the edge, and a cross-like arrangement of fibres at each pole of the proboscis in transverse section; Micrura and Meckelia are also included herein. 2. Carinellidæ—with the lateral nerves between the basement and the outer circular layers, and no head grooves nor medio-dorsal vessel; it includes Carinella, with a short mouth and wide snout; and Valencinia, with a long mouth and narrow snout. 3. Cephalothricidæ have a wide interval between the nerve commissures and the proboscis, armed with

Fig. 22.

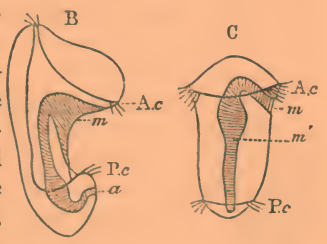


Diagram of Bipinnaria (p. 136) (B), and a worm (C); A.*c*, anterior ciliary crown; *m*, mouth; *m'*, stomach; P.*c*, posterior ciliary crown; *a*, anus.

* Tetrastemma has four eyes in a square. In Prosorhochmus, they do not form a square.

† Meckelia has feeble or no head fissures.

acicular papillæ ; no head fissures. The larvæ are provided with eyes, which are usually absent in the adults.

2. Enopla—nerve ganglia nearly double ; globular, lateral nerve trunks within proper muscular walls ; mouth in front of the nerve commisures, ventral ; no metamorphoses. This includes one family, Amphiporidæ, with two muscular coats only, an outer circular and an inner longitudinal, a proboscis of three parts, anterior or basal, with seven coats, middle armed with the stylets, and posterior saccular, with two muscular coats. The bodies are generally short, with a long proboscis, except in Nemertes. There are three blood-vessels and two cephalic arches.

Rhamphogordius (*Rathke*)—a thread-like, diœcious or monœcious, jointed worm, with only longitudinal fibres and two terminal, proboscis-like lobes, is placed by some among the Enopla, but by *Schneider* is regarded as forming a subdivision of Nematodes under the name Gymnotoma.

CHAPTER XXIV.

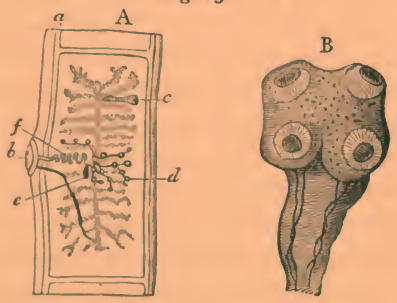
CLASS 2.—COTYLIDEA (*Van Beneden*).

ENDO- or ecto-parasites (sometimes only temporarily so), with cup-like or irregular suckers formed of processes of the muscular lamina of the body wall, covered with skin. They have no body cavity, sometimes no intestine, never an anus, and are ciliated in early life, but shed their outer layer. To this variable group belong two orders :—

1. Cestodea (*Rudolphi*), tape-worms—hermaphrodite, segmented, endo-parasitic, band-like personæ, with no digestive nor vascular system ; nourished by osmose. The first segment (Head, Nurse, Scolex) is

imperforate, rounded, or facetted, and has 2–4 round or elongated, sometimes movable, suckers (Fig. 23, B), and may be armed with hooks of chitin (calcified or silicified ?), acting as anchors, placed often alternately in circlets. The blunt ends of these are in pouches, and their roots thicken with age. There are fine hairs on the head and suckers in Triænophorus, and on the hinder end of the body in Tetrarhynchus. The head may have a central spur (rostellum, cupula), or, as in Tetrarhynchus, a protrusible proboscis, armed with hooks. Behind the suckers are occasionally nerveless red specks, perhaps rudimental eyes. The head is borne on a neck which begins narrow, but rapidly widens into the jointed body, which (except in Caryophyllæidæ) is made up of 2–∞ metameres. The body grows from the head (the oldest part) to the distal end, so that the neck metameres are the newest, and the oldest joints are those most remote from the head. Each segment as it ripens develops reproductive organs, and is named *proglottis*, in which stage it may have a brief separate existence. As the immature segments (Strobila) show an inter-metameral continuity of textures, and as there is a single water-vascular and (when present) nervous system, the entire worm is regarded as a persona, not as a colony.

Fig. 23.



A, Proglottis of T. solium; *a*, water-vascular system; *b*, sexual orifice; *c*, uterus; *d*, testes; *e*, vesiculæ seminales; *f*, vas deferens; B, head of T. medio-canellata.

The component tissues are a chitinous integument, a muscular layer, usually not well differentiated from the connective tissue (parenchyma), which makes up the thickness of the body, and contains the water-vascular system, consisting of two, four, six (Ligula), or eight (Caryophyllæus) lateral canals, which are joined by transverse branches, one at the back of each metamere, and anteriorly unite in arches. In the last (oldest) joint the vessels unite directly in a common excretory pore, in front of which may be a pear-like contractile vesicle. These canals may have a fine muscular coat, by which, or by the contraction of the whole body, the circulation is maintained. They are lined by tesselated, in the finer branches by ciliated epithelium; sometimes lateral branches extend into the muscular layer, even to the surface; and in their finer ramifications, strewed sometimes abundantly through the parenchyma, are concentrically laminated, bright, spherical, calcareous bodies.* The other contents are a clear fluid and small refracting granules. The nervous system is not detectible in Tænia, obscure in others, or consists of a central flat swelling, sending backwards fine branches, as in Tetrarhynchus attenuatus, crassus, and megacephalus.

Reproductive organs occur in every proglottis, and may open ventrally, or in the female ventrally and the male marginally, or in both marginally. In this case, the male organ opens above and the female below, often in a common groove. The marginal openings are rarely at both sides of each segment, with double sex-organs (T. cucumerina, elliptica), but are usually alternate, right and left in successive seg-

* Dissolving without effervescence in acids.

ments. The male organs consist of a testis made up of a cluster of globular, grape-like cæca (Fig. 23, A *d*), sometimes very numerous, thickest above, and disappearing when the contents are discharged; the vas-deferens from each testis dilates into a convoluted tube, which at the sexual orifice ends in a thread-like penis, which, when at rest, is coiled in a sheath. The female possesses separate germigenous and vitelligenous glands, an oviduct, uterus, egg-shell gland, bursa-copulatrix (spermatheca), and vagina. These waste after the extrusion of the eggs. The uterus is usually a convoluted pouch, which, when full of eggs, becomes rosette-shaped, or tree-like. The small oval eggs are yellow or red, with a hard rough shell, and containing many bright yelk granules. These eggs, with their enclosing proglottides, are expelled with the fæces of their host, and the segments crawl slug-like on plants or damp ground, often remaining free for many days. Even after the death of the proglottides, the eggs long retain their vitality. They pass into the stomachs of other animals with the food, the egg-shell softens and falls off, and the liberated embryo (Proscolex) begins to travel through the connective tissues of the body of the new host, or even in its blood-vessels (*Leuckart* found them in the vena portae). This proscolex is an oval or round clear body, with anteriorly six weak, curved hooks, and a ciliated clothing which soon disappears. On reaching a suitable site, the hooks anchor it, and then disappear, and the body becomes stationary. This, acting as a foreign body, causes a local exudation of lymph and development of capillaries around it, nourishing and encapsulating it. The larva dilates into a sac full of fluid (water with about

3 per cent. of salts of soda, and a trace of albumen), whose wall divides into a surface cuticle, and a deeper muscular layer of circular (outside) and longitudinal (inside) fibres, within which is a layer of nucleated cells. At the end where the hooks were in the proscolex, a swelling of the sub-muscular cells takes place, projecting at first equally on the outside and into the saccular body. This grows inward, and divides into two layers, an outer, receptaculum scolicis, and an inner, proper body-wall of the scolex. The latter grows, becomes worm-like, with a dilated, saccular free end often coiled within the former, which becomes flask-like and dilated. The water-vascular system and its concretions early appear in this embryo, and at the widest end of its cavity the suckers and hooks form. This scolex was long thought to be a distinct (cystic) worm, until the researches of *Küchenmeister*, *Van Beneden*, &c., showed it only to be a temporary, immature condition. Cysts of this kind may give rise to colonies (when they are called polycampic) either by the growth of buds from the primary larval sac (Cœnurus), or by the formation within the primary sac of a secondary or daughter cell, which develops new cells by peripheric budding (Echinococcus), or each cyst may only produce a single head (monocampic). These cysts are common in the solid tissues of animals (hydatids, "measles" in pork), and when introduced into the stomachs of other animals, the outer cyst and tail vesicle disappear, being dissolved away, the suckers and hooks develop, and the worm moves in the intestine of its host, sometimes carrying its caudal vesicle with it. Hitherto the young worm has been hollow, but parenchyma rapidly develops after the

second day of freedom, and the body lengthens, and shows transverse lines, deepening into joints.

There are about 265 species, divided into seven families.

1. Taeniidæ—worms of many metameres; head with four suckers (Fig. 23, B); sex openings usually marginal. Gymnotaeniæ have no rostellum nor hooks, and inhabit herbivorous Mammals, Man, Amphibians, and Teleostean fishes. G. mediocanellata (Fig. 23, B), with a black ring round each sucker, dichotomous uterine pouches and oval eggs is a common human parasite in this country, Siberia, Abyssinia, &c., and sometimes is 1200 jointed. G. perfoliata and plicata occur in the horse. G. dispar in frogs. G. pectinata in hares. Echinotaenia has a rostellum and 1-4 circlets of hooks, and is parasitic in Carnivores and Omnivores, Man, &c. E. solium, the common tape-worm of Western Europe, has two alternating circlets, one of larger, one of shorter hooks, twenty-six in all, each with a short process at its root, and often black hook follicles; the uterine follicles are dendritic, and contain spheroidal ova; its larval stage (Cysticercus cellulosæ) is the parasite of measly pork. E. echinococcus, of the dog, rarely in Man (Iceland), consists only of 3–4 metameres, and has a rostellum; its scolex is the hydatid of the human liver (Echinococcus hominis). E. crassiceps, of the fox, develops from Cysticercus longicollis of the field-mouse. E. elliptica, of the cat, once found in a child, has double sex-organs in each proglottis. E. acanthotrias is only known in its scolex stage as a human parasite with three rows of hooks. E. platycollis is developed from the human C. turbinatus (*Köber*). E. nana, found in an Egyptian boy, has an oval rostellum with one row of hooks. E. marginata, of the dog and wolf, rarely in Man, develops from C. tenuicollis of ruminants and swine. E. flavo-punctata, named from the colour of the seminal vesicle when full, was once found in Man. E. serrata, of the dog, from C. pisiformis, of the hare; E. crassicollis, of the cat, from C. fasciolaris, of the rat and mouse. E. cœnurus, with a rostellum and two rows of hooks, in dogs, develops from Cœnurus cerebralis of the brain of sheep, which produces the disease known as the "staggers."

C. serialis is a similar scolex in rabbits. E. acanthorhynchus a short, oval form, from the intestine of the black-necked Grebe, has a long rostellum with 8–10 rows of hooks. As *Leuckart* has shown that some Tæniæ early lost their rostellum and hooks, other divisions of these worms have been proposed as Sclerolepidota (with hard egg-shells), and Malacolepidota (soft egg-shells) by *Weinland*, or Cysticæ and Cysticercoidæ by *Leuckart*. Family 2. Dibothria—jointed worms, rarely with hooks, and with two opposite suckers on the flattened head, placed somewhat like the sense-grooves of Nemerteans. Bothriocephalus, with its suckers corresponding to the margins of the body, includes B. latus, the tapeworm of Europe, east of the Rhine, sometimes thirty feet in length, and with 5–10,000 joints, with wide segments and genital organs opening centrally (marginally in B. longicollis of the fowl); the uterus forms a rosette, and the eggs are oval; within these are developed ciliated proscoleces with six hooks. Under this ciliated integument a cuticle forms, and the ciliary layer is shed; the scolex is free, aquatic. They are said to abound where lake-water is used for drinking. Dibothrium has its suckers corresponding to the surfaces, not to the margins. D. claviceps, of the eel, and D. proboscideus, of the salmon, have marginal sex orifices. D. punctatum, of flatfish, and D. cordatum, a human parasite in Greenland, with an abundance of calcareous concretions, have ventral openings. Family 3. Diphyllidæ—jointed; head with two suckers; two rostella armed with vertical hooks; neck bristled. Echinobothrium, a selachian parasite, has its larvæ in Crustacea and Molluscs. Family 4. Tetraphyllidæ—jointed, with four movable suckers, sessile or stalked; this group includes three sub-families. Phyllobothrinæ, with soft, hookless suckers, selachian parasites. In Echeneiobothrium, the proglottides grow as large as the entire strobile, and the suckers are ridged like those of Echeneis. Tetrabothrium and Anthobothrium also live in sharks and rays. Phyllobothrium delphini has been found self-impregnating. Phyllorhynchinæ—neck thin or swollen; suckers four, and four retractile proboscides armed with hooks. Tetrarhynchus is found mostly in sharks; its scolex is known as Anthoce-

phalus, found in Teleostean fishes. Pterobothrium inhabits Trichiurus. Phyllacanthinæ have the suckers each armed with 2–4 hooks. Acanthobothrium is a fish parasite. Family 5. Ligulidæ—body only weakly transversely striped; head not separate; suckers, 2, developed late; middle of the body with a long furrow. The series of medio-ventral sexual organs alone indicates the number of component metameres. The proscoleces resemble those of Bothriocephalus. Some multiply by buds, and their immature forms are found in fish, their perfect forms in fish and water fowl; some are viviparous. They are found often in the peritoneal cavities of carp, minnows and sticklebacks. Family 6. Caryophyllæidæ—body flat, unjointed, of one proglottis; fimbriated or sub-globose in front; a transverse, two-lipped sucker lies at the front end; the body consists of a sexual and an asexual (anterior) part; both sexes may have their organs opening together medio-ventrally, or the penis may be anterior; evolution is direct. Caryophyllæus mutabilis is found in the carp. C. punctulatus in the conger; Eustemma, in Falco pileatus, has the female opening on a sub-conical, retractile eminence; Monobothrium and Diporus in fishes. Family 7. Amphilinidæ—one-jointed parasites; passage forms to the next order, placed here as they have no trace of a digestive canal, except an anterior muscular cæcum (a modified sucker (?) or rudimental pharynx); with a single sucker and branched water-vascular system, and the oviduct opening near the head. The development resembles that of Trematodes, ex. Amphiline, Amphiptyches. Gyrocotyle, from the pygarg, has a gyrately-folded sucker and a dorsal pore to the water-vascular system; in some points it seems to be related to Malacobdella. *Diesing* places these in the next, *Wagener* in this order.

CHAPTER XXV.

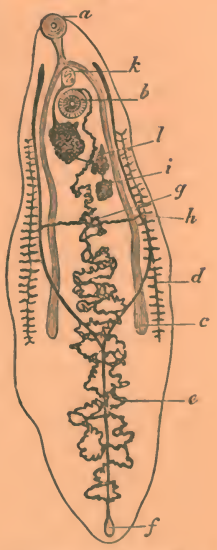
ORDER 2.—TREMATODA (*Rudolphi*).

FLATTENED, lanceolate, or oval, mono-metameral, endo- or ecto-parasites, with one or more ventral suckers, and two pharyngeal nerve ganglia united by a flat commissure, sending off weak lateral nerves with no neurilemma, a branch to the oral sucker and one to the digestive organs; a ganglion sometimes underlies the ventral sucker (Distoma lanceolatum). The cuticle is armed with bristles, spines, or scales, which constitute a head armature in D. echinatum, militare. The dermis is cellular or protoplasmic, over a strong trilaminar muscular stratum, whose inner, circular lamina mostly consists of spindle-cells, and a connective parenchyma making up the chief bulk. The suckers have strong, radiating, and weaker circular fibres, and in the centre of the anterior one (except in Polystomidæ) is the mouth, leading into the muscular, suctorial, often globular pharynx. A narrow œsophagus joins this to the intestine, which is usually an excavation in the parenchyma, lined by cylinder epithelium, and with no muscular coat;* it is rarely simple (Aspidogaster, Gasterostomum); usually forked or branched, aproctous; the branches are usually cæcal, rarely anastomosing;† some, perhaps, hepatic. In D. filicolle, the intestine disappears in the adult.

* A muscular coat is described by *Leuckart*.

† The two limbs of the intestine may unite to form a ring (Gynœcophorus), which gives off branches (Epibdella, &c.), sometimes giving off a central azygous process (Polystomum integerrimum).

Fig. 24.



Distoma lanceolatum; *a*, anterior sucker; *b*, posterior sucker; *c*, intestine; *d*, yelk gland; *e*, uterus; *f*, porus excretorius of (*h*) the water-vascular system; *g*, oviduct; *i*, ovary; *k*, cirrus in its pouch; *l*, testis.

The water-vascular system consists of two lateral, non-retractile, ciliated vessels, opening behind by a common pore, or separately (Tristomum). There may be a contractile, non-ciliated sac at the junction of the two tubes (Fig. 24, *f*), or they may be united in a ring (D. rachiæum), or may form a fine netted canal system (D. dimorphum). The contents are water, guanin, and calcareous concretions. The circulatory system is rarely definite. Tristomum papillosum has a median tube, giving off lateral branches. Small (poison ?) glands surround the anterior sucker, and open outside the mouth. Some larvæ and ectoparasites (Amphistoma sub-clavatum and Dactylogyra) have black pigment flecks (eyes) in some cases, with rudimental, crystal cones. The sexes are separate in Gynœcophorus, Distoma filicolle, Wedlia bipartita; others are hermaphrodite. The female organs are, a germ-gland, two yelk glands, an oviduct, uterus (a long coiled sac), an azygos shell-gland, a vagina, and a receptaculum seminis. In D. hepaticum, the common duct, before it ends in the shell-gland, sends a duct backwards to the surface. The male organs are two rounded, tubular testes, a vas deferens, vesicula seminalis, and an ejaculatory duct, ending in a penis (cirrus), which is protrusible from its pouch. Sometimes a canal runs

from the oviduct to the testis to ensure self-impregnation. The sex-organs always open medio-ventrally. Gyrodactylus elegans is viviparous. The eggs are often of odd shapes, and may be developed directly or metagenetically. The embryos of some are non-ciliated (D. tereticolle, variegatum).

There are two sub-orders :—

1. Monogenæa—eggs large, often angled, pillared, or filamented, with thick shell ; development direct ; young not ciliated. Ecto-parasites on the skin and gills of fishes, crustaceans, &c. This includes six families :—1. Octocotylidæ—long ; hinder part of the body lengthened as a tongue-like lobe, armed with eight suckers in two rows ; two suckers beside the mouth ; body armed with hooks about the genital pore. Microcotyle has small suckers and posterior hooks ; Gastrocotyle has over thirty little suckers posteriorly, and the front of the body is narrow ; Phyllocotyle has two anterior and six hinder suckers, and a tail armed with a sucker and hooks. Anthocotyle is club-shaped in front, with two small suckers, and has posteriorly six small, stalked suckers ; at the hinder point of trisection are two oval side suckers, with frilled hinder margins, and each ending externally in a stalked sucker. In Diplozoon, a carp parasite, the individuals, when they attain maturity, unite in pairs (like the Siamese twins) at their hinder point of trisection, becoming x-shaped. Each single individual has two fore suckers, and two hinder areas each with four suckers. The sex-openings are behind the point of union. The cirrus is spiral, 2½ times as long as the whole body. Choricotyle has posteriorly eight suckers on long stalks, a crown of hooks round the sexual opening, and two small front suckers. 2. Gyrodactylidæ—minute, fish parasites, with two anterior suckers ; the hinder part of the body dilated, margined by small hooks, and armed with two, long, recurved hooks ; pharynx protrusible, with a papillary margin anteriorly ; water-vascular stems 4, of which only two end in the pore. Gyrodactylus is found in carp, &c. ; in these, second embryos may be developed within the first,

formed before their expulsion from the mother. 3. Polystomidæ—with an anterior small, and six posterior larger suckers on the flattened margin; hooks 2 (Polystoma), or 8 (Erpocotyle). Two of these have been found as human parasites, Polystoma pinguicola (ovary, *Treutler*), and Tetrastoma renale (kidney, *Dellè Chiaje*). 4. Udonellidæ—leech-like; minute; front of body with or without lateral suckers; intestine simple; hinder suckers sessile, with no hooks, often found on Lerneæ. 5. Myzostomidæ—aberrant, monœcious forms; ecto-parasitic on Comatula, and with possible affinities to Chætopoda, to Tardigrada, or Crustacea; discoidal, soft, surrounded by cilia, with latero-abdominal suckers, and hooks like those of other trematodes; a protrusible proboscis; a wide stomach; a narrow dendriform intestine, *and an anus!* They have holoblastic ova, and ciliated, cylindroid larvæ, which develop two pairs of processes like rudimental feet; these increase to five pair, and resemble the parapodia of Chætopods; in M. cirrhiferum, each bears a bristle; the nerve system has a pharyngeal commissure and a few ventral gangliform swellings; the male sex-organs are double, and open with the intestine; the testes are branched pouches; the female organs open separately (*Lovén*) or with the intestine (*Semper*). 6. Tristomidæ—hinder sucker large, radiated, with or without a stalk; in front are two round or long lateral suckers; intestine branched, with sex openings separate on the left side. Cyclatella has a crown of tentacles; Tristoma has hooks on the hinder sucker, ex. Callicotyle, Epibdella; some have eye-specks.

Sub-order 2. Digenæa (*Van Beneden*)—eggs small, numerous; development metagenetic; the egg emits a variably shaped larva, with or without cilia, sometimes with a touch papilla and two lateral plates anteriorly; within this larva arises a cylindrical, tailed body, which becomes free, and may possess a mouth, pharynx, and water-vascular system, opening outwards *and into the body cavity.* This form sheds its outer ciliated layer, and is known as a Redia. Sometimes the water-vascular system extends into the tail, and there may be a pulsating vesicle there. In other cases, the larva develops within itself a rounded, or worm-like, tail-less,

organ-less sac (Sporocyst or Blastocyst, *Diesing*), which may undergo transverse fission. In the body cavity of a Sporocyst, by internal gemmation one or many daughter cells are produced, which resemble the parent. Within these, or within a Redia, form, as internal buds, numerous small, oval bodies, Cercariæ, with movable, sometimes forked tails (Bucephalus); these become free, and are expelled through an opening in the "nurse," and for a time enjoy free life in water or on moist ground. They have two suckers, with the mouth in the foremost, which deepens into a pharynx and intestine; the water-vascular system then develops, and the animal is either swallowed by the host in which it is to be developed, and becomes at once mature, or it burrows into the skin, or into the pulmonic cavities of freshwater Molluscs, &c., and loses its tail, becomes surrounded by a cyst, and becomes a pupa, in which, when its host is eaten by some other animals, and it is set free in the stomach, the sexual organs develop, and the adult forms are assumed; some encapsulate themselves in plants, and are thus eaten.

The sub-order includes four families:—1. Monostomidæ—one sucker (oral); sporocysts in Planorbis; perfect forms in water-fowl, &c. Monostomum lentis has been found in the capsule of the human lens. 2. Amphistomidæ—a sucker at each end; Diplostoma in the lenses of fishes' eyes; Amphistoma in frogs, ruminants, &c. 3. Distomidæ—suckers, 2; one circum-oral in front; one ventral; never terminal. This includes the bristled and two proboscis-bearing Rhopalophorus,* and the diœcious Gynœcophorus (Bilharzia) hæmatobius, common (110 times in 360 subjects, *Griesinger*) in the venæ portæ of Egyptians and Nubians. In these, the male has a large abdominal groove, with two lips, in which the cylindrical female is contained. The eggs are oval, with a terminal or lateral spine. Distoma is hermaphrodite, and may be divided into two sub-genera:—(α), with branched intestine, including the ovate D. hepaticum, of the sheep, and rarely

* The proboscides limit the mouth at each angle. These are parasitic in Opossums. The spines are in rows along the proboscis. R. horridus is spined over the body.

of the human liver, about $\frac{3}{4}''$ long, with bristled and apparently puncturated surface; suckers small, close together, with the sex-opening between them. D. Goliath lives in the hepatic duct of Balænoptera rostrata; D. Jacksoni in the Indian elephant; D. clavigerum develops from the Cercaria of Planorbis; D. clavatum is found in the swordfish; (β) intestine not branched; uterine pouches reaching the end, as D. lanceolatum the elongate fluke of the sheep (fig. 24); rarely in Man; D. crassum and heterophyes also rarely human; D. trigonocephalus in the otter; D. ophthalmobium found in the eye of a child; D. echinatum in wading birds; D. squamula of the polecat; D. neuronaia has its pupa in the nerves of the haddock: its perfect state (Gasterostoma gracilescens) in Lophius. 4. Dicyemidæ consists of problematical, ovate, immature, microscopic, ciliated forms, found in the venous sinuses of the kidneys of Cephalopoda, with oval or cordate head lobes. Planuliform or worm-like larvæ develop within them. Several species are known, which may be immature rhabdocœlous Turbellarians, but are most probably Rediæ of unknown Trematodes; two clear lateral streaks are probably water-vascular tubes.

CHAPTER XXVI.

CLASS 3.—NEMATELMIA (*Vogt*).

CYLINDRICAL, unjointed, mostly diœcious, parasitic worms, with usually a distinct body cavity, and a rudimental, non-ciliated, water-vascular system; but no suckers, bristled ambulatory papillæ, respiratory, nor circulatory organs. There is no metameral division, but the dermis is often ringed; the nervous system is often well developed, and the intestine has usually an anus. Development is direct.

Two orders are included :—

1. Gordiacea (*von Siebold*)—long, thread-like, elastic, aproctous, with a firm, fine cuticle, and a faintly fibrous basement, covering a layer of longitudinal fibres (which are flattened bands, with their flat surfaces in contact with each other), only interrupted along the median line. The water-vascular system is absent (Gordius), or represented by a row of cells (Mermis). The short œsophagus passes from the mouth to end in a bulb (Mermis), or in an intestine (Gordius) opening into the body cavity. The nervous system is feeble, but of the nematode type. The sexual organs consist of simple tubes, developed in the peri-enteric connective tissue, at the expense of the vanishing digestive organs, and opening posteriorly (the female opening may be central in Mermis). They are parasitic in insects for some part of their life, free at other times ; when mature, they live mostly in water or mud, where they reproduce, and their young either return to their insect hosts (Mermis) or undergo metamorphosis. They reproduce in large numbers, and so suddenly do the young of M. albicans appear in favourable seasons, as to give rise to the belief that they have fallen with rain. The larvæ have one or more cephalic boring spines, sometimes (Gordius) an armature of recurved hooks.

There are three families and about thirty species :—
1. Gordiidæ—yellowish brown, or black, with an intestine ; head not papillose ; females entire or forked at the tail ; uterus one-horned ; males forked, with the spicule-less sexual opening in the fork ; eggs pear-shaped. Gordius begins life free, with a retractile spiny proboscis and a transversely wrinkled body ; it enters some aquatic insect, and becomes

encysted therein; its perfect forms are found in Orthopterous or Neuropterous insects, which it again leaves for reproduction, and becomes free, losing its mouth and intestine. 2. Mermidæ—thread-like; œsophagus short; head papillary; tail undivided papillary in the male, with a double penis (spiculum, spermategæ of *Diesing*); egg-shells often with brush-like tassels; eggs not in chains as in Gordius; uterus two-horned; larvæ with single cephalic spines, found in Lepidoptera, &c. 3. Sphærularidæ—in the body cavity of Bombus; with no mouth nor œsophagus (or a mouth opening into the body cavity?); skin with vesicles; male small, $\frac{1}{28000}$ of the size of the female, to which it is organically fastened; female with a simply tubular ovary, a terminal genital opening, and two rows of large cells in the body cavity.

Order 2. Nematoda (*Rudolphi*)—free or parasitic round worms, with a smooth, never ciliated, sometimes double refracting cuticle; rarely with bristles or lateral wing-like expansions beside the head (these are sometimes inconstant, as in Ascaris dactyluris). This layer is chitinoid, and sometimes makes the body stiff, but is less resisting to re-agents than the chitin of Arthropods; it is traversed by fine pores, often annulated, transversely striped, or laminated, the superficial layers being the most chitinous. The dermis is thinner, obliquely striated, made of granular protoplasm, and longitudinal and vertical connective fibres; it is often traversed by laminæ, and sometimes contains unicellular glands. In Trichocephalus, there is a ventral row of rod-like bodies in the dermis. In Trichosoma, a ventral and dorsal row; in others, nail-like rods. Young nematodes usually moult several times. The muscular lamina, thicker than the integument, as it is in most Vermes, consists of two sets

of large,* flattish, spindle-shaped, longitudinal fibres, either continuous (Trichocephalus) or divided into dorsal, ventral, and lateral tracts, separated by thickenings and prolongation of the cutis. Sometimes vesicular processes are appended to the fibres (tracheal sacs of *Bojanus*), and in some the processes of the muscular fibres unite with the nerves, or run into the neurilemma, especially around the pharyngeal ring, reminding us of the neuro-muscular cells of Hydra. The muscle fibres may be solid, flat (Platymyaria), or tubular (Cœlomyaria), with a striated wall enclosing granular protoplasm, continuous with that in the vesicular swellings.

The nervous system consists of an œsophageal ring covered by multipolar ganglion cells, surrounded by a sheath, sending forwards two branches in the lateral field, and four in the mesial line, some of which go to the oral papillæ; ganglion cells lie in the course of these. Behind, the ring gives dorsal and ventral branches; two of the latter often speedily unite to form a ventral (cephalic) ganglion, and in some young forms post anal ganglionic enlargements exist. Touch papillæ exist in some; perhaps the oral lobes may be of this nature. Nerveless eye specks exist in some free forms, while true eyes are present in the free genera, Enoplus and Urolabes.

The mouth is anterior, surrounded by lips or papillæ, which sometimes become chitinized as jaws; it is rarely cup-like (Cucullanus). The œsophagus is narrow, often gradually thickening, surrounded by circular fibres in some (Heterakis, Oxyuris), separate

* In Strongylus gigas each is 4 *mm.*; Ascaris lumbricoides 3 *mm.*; Dochmius hypostoma 2 *mm.*

from the body wall, to which it may be suspended by mesenteric strings. Little spines sometimes arm its oral end, even in embryos (Enoplus and Anguillula). In Ascaris megalocephalus there is a gland in the œsophagus opening outwardly. In Cheiracanthus aculeatus, of the tiger, four cæcal (salivary ?) glands open into the mouth; while a lining of gland-cells in the œsophagus is not uncommon. In some, the œsophagus acts as a sucking tube, and is divided into a glandular and a suctorial part. The so-called stomach is distinct, muscular, often globular, sometimes with a chitinous, gizzard-like lining, and may be suctorial, the true stomach then being the dilated end of the straight intestine, into which this gizzard opens by a narrow pylorus. The intestine has a glandular lining, a muscular coat (for its lower third only in some), and it is held in its place by thick, interrupted, cellular mesenteries, the appendices nourricières of *Cloquet.* The anus is ventral, longitudinal, sometimes sub-terminal or terminal (Trichina, Trichocephalus), absent only in one family; glandular cæca often occur in the course of the intestine. Anguillula appendiculata has one from the intestine, Asc. halicoris from the stomach. The body cavity contains a perivisceral fluid (blood ?), in which a few oval and amœboid corpuscles float. A water-vascular canal lies in each of the thick lateral lines of the dermis; these open by a common medio-abdominal pore, usually at the level of the muscular stomach. They are seldom absent, branched in Strongylus auricularis, and forming a ribbon-like lateral organ in Filaria. The four circum-anal cæca in Ascaris dactyluris, which open by narrow ducts within the anus, may be excretory organs, possibly renal.

The sexes are separate, except in Pelodytes, Filaria, and Ascaris nigrovenosa. The organs are large, and produce large quantities of sexual products. The male possesses one, rarely two, ventral, convoluted, tubular testes, ending in a vas deferens leading to a seminal vesicle, often villous within. The duct opens beside the anus, and is armed with one or two chitinous spicules, arising from muscular pouches. The epithelium of the testis is ovoidal, of the vesicle and duct flatter. The female possesses 1–5 convoluted tubular ovaries; usually two, uniting at the pre-anal, often medio-ventral, vagina, which equals the spicula in length. Sometimes there are two papillæ midway between the anus and tip of the tail, in Pelodera appendiculata prolonged into ribbon-like appendages. The first part of each ovary may be germigenous, the next part vitelligenous, and this may join the terminal dilated part or uterus by a narrow tube (Leptodera appendiculata). The sexual tubes are first filled with granular protoplasm, which forms a central rachis, on which the eggs or the mother-cells of the spermatozoa develop. In some of the few hermaphrodite forms, both products develop in the same tube, sperm-cells first, afterwards ova, as in the parasite form of Ascaris nigrovenosa (which has a female appearance). Some species are viviparous, others lay hard or soft-shelled eggs, a few have a metamorphic development; thus Urolabes palustris is the larva of Filaria Medinensis. The eggs of Dochmius trigonocephalus of the dog develop into Rhabditis-like forms in water, and after several moults, again enter the dog's intestine with its drink, and in twenty-four days lose the stomach teeth, and

assume the adult form. Some of these larvæ have been found retaining the Rhabditis form in the mollusc Physa. Ascaris nigrovenosa lives as a hermaphrodite form, often 12 mm. long, in the lung of the brown frog, and produces ova. The young, bred from these, enter the cloaca of frogs, and assume a Rhabditis form, with short, pointed tails; these become free, diœcious, in mud or water, and produce eggs, which emit Rhabditoid embryos, often in the uterus, and then entering into frogs, again moult, lose their teeth, and develop forms like the original Ascaris.

Passive wandering occurs in some forms; thus some Strongyli begin life in Fish, and end in fish-eaters. Cucullanus elegans begins in Cyclops, and with these enters the stomach of fishes. Active wandering occurs in Trichina spiralis, &c. Some forms have a boring cephalic spine. About 900 species are known.

They are divisible into four sub-orders:—

1. Rhabdophora—free, marine, slender, bristled; with two rows of pre-anal cylindrical rods, whereby they creep. Chaetosoma has 2-15 pair of straight rods; males small, with two spicula; females with two spermathecæ and pre-centrally opening vagina. Rhabdogaster has many short, curved rods, in the midst of which is the female orifice. This genus has no cephalic hooks, while the former has movable hooks in a double series. These appear to be the nearest allies of Chaetognatha.

Sub-order 2. Cystoopseadæ—imperfectly known, aproctous parasites (under the breast-shields of the sterlet), with thread-like males and oval cystic females (*Wagner*).

Sub-order 3. Hypophalli—rod-like appendages none; penis ventral, in front of the tail. This includes fourteen families:—1. Cucullanidæ—parasitic; head distinct. Cucul-

lanus has two apical shell-like valves based on a chitinous ring, sending off processes. Lecanocephalus has a patelliform head, a spinulose body, and a sword-like penis-sheath. Heterocheilus, of the Manatee, has a short neck and three unequal lips. Conocephalus, of the Dolphin, has a conical head with a retractile border, a simple uterus, and two ovaries. In Ancyranthus, of the Tortoise, the head is armed with 4–8 pinnatifid spines, with two long central and two small lateral, bicuspid spines; in Elaphocephalus, found in the sheath of the digital tendons of a macaw, and in Aspidocephalus, the head has lateral leathery shields and a central mouth. 2. Cirrhostomidæ—free, thread-like; mouth cirriferous; a caudal gland opening at the tip of the often papillary, bifid tail; stomach not globular. Phanoglene has two large cervical eyes. Enchelidium has one postoral pigment mass, with several lenses. The tail has no papilla in the marine Pontonema; it is suctorial in the freshwater Amblyura. Oncholaimus has two or three, and Odontobius has 3–6 teeth. Enoplus has 2–4 teeth and red eye-specks. 3. Anguillulidæ—stomach muscular; pharynx seldom with chitinous teeth; no caudal gland. Dorylaimus has a central stilet-like tooth in its protrusible proboscis. Diplogaster has several teeth, as has Rhabditis, the vinegar and paste eel. Anguillula—free or parasitic; has no teeth nor penial sheath. Myoryctes is parasitic in the muscles of frogs. Pelodytes is hermaphrodite (in Mollusca). Angiostomum has chitinous, pharyngeal plates, and no stomach. Leptodera is bilabiate, and has, like the last, a two-bladed penial sheath. 4. Hedruridæ—mouth two-lipped; the straight females have a hinder sucking groove with a central hook; the males are coiled; penial sheath, none (Hedruris), or double (Symplecta). 5. Ophistomidæ—mouth two-lipped, ventral; head cup-like (Stelmius), or rounded, continuous with the body; sometimes with a chitinous support (Dacnitis); female tail unicoronate (Ophiostomum), or bifid (Rictularia). 6. Spiruridæ—long, with terminal mouth; head papillose or lipped; hinder end of male coiled, winged (papillose in Eucamptus) mouth, with one papillose, circular (Spirura), or two lips (Cheilospirula), or none (Spiroptera); S. hominis

has been found in the human bladder. 7. Tropidocereidæ—male slender; female sub-globose, with four longitudinal bands; neck with two basilar spines. 8. Cheiracanthidæ—body armed as far as the middle with pointed lateral lamellæ; head bristled, two-lipped; penis not sheathed; in cats, tigers, alligators, &c. 9. Physalopteridæ—males with a winged tail-vesicle filled with a clear fluid; mouth bilabiate, papillose outside, toothed within; in alligators and Mammals. 10. Ascaridæ—mouth with three labial lobes, and sometimes touch papillæ; stomach often with teeth. The penis in Ascaris is thread-like, with a two-leaved sheath. A. lumbricoides is the common human round worm, also in the orang, swine, &c.; 5–11″ long; tapering to each end; each lip has many (200) papillæ; the females are largest, and, as in other species, the most numerous; the vagina opens at the anterior third. A. mystax, of the cat, is winged at its head. A. acus, of the gar-pike, has linear wings. A. heteroptera has inequilateral wings. Haligmus has a spiral, sheathless penis. 11. Oxyuridæ—long, with naked or spiny tails; mouth terminal, papillose, or lobate; teeth pharyngeal (Passalurus), œsophageal (Pharyngodon, with no penial sheath), or at the junction of the pharynx and œsophagus (Heterakis). Oxyuris has no teeth; the tail is acute in the female, papillose in the male. O. vermicularis is the human thread-worm. Cosmocerca is four-lipped, and has a ventral horny plate. Tachygonetria is viviparous. 12. Ptychocephalidæ—thread-like; head sub-globose, with five radiating folds; œsophagus with three horny grooves; in beetles. 13. Filaridæ—hair-like; mouth round; penis thread-like, with one or two leaf-like sheaths. Filaria Medinensis, the Guinea worm, is viviparous, and begins life as a form like Urolabes; pierces the skin of bathers, then develops in the cellular tissue, and may attain the length of several feet. F. capucinus has been found in American monkeys. F. lentis in the human eye. F. Loa in the eye of a Negro. Filaroides, of the polecat, is ringed. Gongylonema, of the mouse, has in front a longitudinal series of bulbilli. 14. Liorhynchidæ—mouth in the centre of a protractile tube; found in fishes.

Sub-order 4. Acrophalli—proctuchous; penis terminal.

This includes two families :—1. Strongylidæ—cylindrical, long, with a disc or vesicle at the tip of the tail, from which the penis arises; some have a terminal mouth with six (Deletrocephalus) or 4–8 converging, chitinous rods (Diaphanocephalus); others have a chitinous ring around the head, and a mouth inferior (Dochmius, D. duodenale, of the human duodenum, is common in Egypt) or terminal, and the penis surrounded by three papillæ (Stephanurus), or with a two-leaved penis sheath (Sclerostomum). The young of S. tentracanthum has a free Rhabditis form. Metastrongylus longevaginatus, with a bilobed male disc and two long yellow spicules, has been found in the bronchial glands of Man. Ollulanus is found in the stomach of cats. Eustrongylus in the human kidney. 2. Trichotrachelidæ—body long, with a thread-like neck; the spiral males have a simple spiculum, sometimes with no penis sheath (Trichina). This form lives encysted and sexless in the muscles of Man, swine, &c.; but when set free by being swallowed, the sexual organs develop, young are produced, which burrow and become encysted in the muscles; the males have two terminal tubercles, one anal and one genital. Onchocerca reticulata, of the muscles of horses, is closely allied. Trichosomum has a tubular penis sheath, and a short neck. In T. crassicauda, of the rat's bladder, there are pigmy males without spicula in the uterus of the females, as well as free living males with spicula. Trichocephalus, the common hair worm of the human cæcum, has a long, thread-like neck, a swollen body, and a vesicular, echinulated penis sheath; its muscle layers are rudimental.

CHAPTER XXVII.

CLASS 4.—ACANTHOCEPHALA (*Rudolphi*).

CYLINDRICAL, diœcious parasites, with a protrusible proboscis, armed with transverse or oblique rows of strong recurved hooks, resembling that of the strongyloid genus Hystrichis; at its base is a sheath, within which it may be retracted by four lateral retractor muscles. This organ is attached to, and often imbedded in, the wall of the intestine of the host. The yellow cuticle is sometimes armed with chitinous hooks, and always traversed by pore-canals, whereby nutrition takes place. Beneath it and the protoplasmic dermis is a layer of striped, circular, and longitudinal muscular fibres. Three laminæ of muscle lie in the wall of the proboscis sheath. There is no mouth nor intestine. A nerve ganglion lies at the base of the proboscis, to which it gives two branches. Two or more lateral nerves pass backward. In the muscular layer are many branching* canals, with two chief lateral stems, extending forwards. These have no special walls, so the granule-holding, often red, fluid within them is moved by the contraction of the body and the motions of the proboscis. Possibly this may be a nutritive apparatus like the gastro-vascular canal of Cœlenterata. The lateral stems end in a circular vessel in the neck, from which, branches pass to the proboscis. With the stems of these proboscidean vessels canals communicate from two band-like

* Not always much branched. In E. porrigens the branches appear in some young specimens to be few, straight.

organs (lemnisci), which lie directly behind the proboscis, each of which has a central large vessel giving off many close branches. Although these vessels do not open outwards, yet they probably form a water-vascular system; the smaller vessels of the lemniscus and those of the body wall do not anastomose. From the base of the proboscis a central connective band is continued backwards, which supports the sexual organs (ligamentum suspensorium; *Lèspes* describes a rudimental intestine and gland attached to this). The males are smaller, and have a hinder sucker used in copulation, in the middle of which is the protrusible penis, with two retractor muscles at its base. They have also 2–3 testes whose ducts opens into a common vas deferens, dilated into several vesiculæ seminales. The females have an ovary, which may fill the whole body, often divided longitudinally, and emitting the ova by dehiscence. A bell-shaped uterine funnel receives these, and they pass out by a short vagina at the posterior end of the body. The fusiform eggs have no germinal vesicle, and the embryo forms peripherically in them. The eggs are eaten by Amphipods, Isopods, &c., and their embryos appear as hook-armed gregariniform worms.* These burrow out of the intestine, lose their hooks, become encysted, and are eaten in this stage by fish, water-fowl, &c., in which they finally develop. The musculo-vascular layers develop from the outer embryonic lamina, within which the nerves, proboscis, and genitals arise.

Echinorhynchus is unsegmented. E. gigas inhabits the intestines of Swine, and was once found in Man (*Lambl*); E.

* The embryo of E. claviceps has no hooks at first.

porrigens, the lesser Rorqual and Eider duck. E. major, the hedgehog. Paradoxites, found in owls, is divided into metameres, of which the first (proboscis-bearing) and the last three are large.

CLASS 5. GEPHYREA (*Quatrefages*). — Diœcious marine, oval, elongate, or sac-like, sometimes ringed, but never jointed, nor with locomotory processes, varying from ½″ to 1′ in length. The cuticle is chitinous, sometimes with papillary thickenings, rarely with cnidæ (Anoplosomatum Antillense). The dermis consists of connective tissue, containing no spicules, but numerous follicular dermal glands sometimes imbedded, or on papillary elevations. Some of these are round, each containing four vesicles around a cellular, expanded nerve-ending, sending four bands into the vesicles (organs of *Semper*). Some have bristles in rows on the surface, and in Bonellia the skin contains chlorophyll. The muscular coat is thick, striped, with outer circular and inner longitudinal fibres, often netted, and closely attached to the skin. The body cavity is ciliated within. The nervous system consists of an œsophageal ring with a single or double dorsal ganglion (Sipunculus, Sternaspis), sending backward a ventral cord in the body cavity; rarely outside the muscular lamina (Priapulus). Only in Echiurus are there faint successive swellings on this cord, and in Sipunculus there is a terminal swelling giving off branches. These appearances and the rudimental partitions in the body cavity of Phascolosoma are indications of metameric division. The ventral cord has a contractile connective sheath (of two laminæ separated by soft cells) continued on the lateral branches, which may be irregular, symme-

trical (Sipunculus), or alternate (Phascolosoma). In Sipunculus, some filaments unite with the circular muscular fibres. Eye-specks are present in a few adults, and the larva of Sipunculus has four, close to the ganglion, but vanishing in development. The front of the body in some is prolonged into a proboscis, usually retractile by means of two or four muscular bands from the body wall, and ciliated, often armed with bristles, and sometimes surrounded by tentacles. The mouth is terminal or slightly ventral (Sternaspis), and the pharynx is armed in Priapulidæ with horny teeth. Salivary cæca open herein in Sipunculus (*Keferstein* and *Ehlers*). The intestinal canal is ciliated within and without; small in calibre; slung by mesenteric threads; rarely by a membrane; it may be scarcely longer than the body (P. brevicaudus); or more usually, long and coiled. (In an Echiurus of 6″ it measured 3½′.) Its middle region is glandular, often yellowish (hepatic ?), as in Bonellia; or with numerous glandular cæca appended (Phascolosoma). The oral, gastric, and intestinal regions are distinguishable in the young, sometimes in the adult (Priapulus). The anus may be dorsal, sometimes anterior, even at the junction of the body and proboscis, or terminal.

There may be no vascular system, or it may consist of two long vessels, one along the medio-ventral line, giving off many branches to the intestine and the wall of the body, and one dorsal running along the intestine, and often coiled with it.

In Sipunculus these are joined by a circumoral vessel, which sends prolongations into the hollow tentacles, and has appended to it one or two contractile sacs like the Polian

vesicles of Echinoderms. This portion has been described as a special tentacular or aquiferous system. Similar cæca may be appended to the dorsal vessel; but when there are no tentacles, this canal breaks up into fine branches anteriorly. In those with no vascular system (except Halicryptus) there is a posterior opening, capable of voluntary closure, into the body cavity, whereby water can pass in and out for aerating purposes (?) A similar anterior opening I have found co-existing with a vascular system in several genera. The fluid in the circulatory system may be colourless, pale red, blue or violet. There may be a similar fluid in the body cavity containing amœboid, flagellate, and ciliated (?) corpuscles.

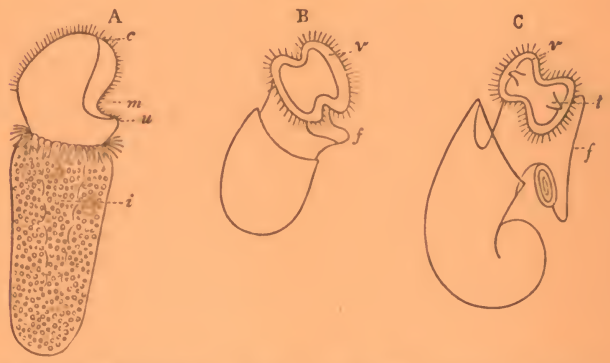
Priapulus has at its hinder end a fimbriated tuft, which may be respiratory. Echiurus has opening into the intestine, at its lowest part, branched organs, receiving vessels from the ventral trunk, like the tree-like organs of Holothurians, which are either excretory or respiratory. There is a rudiment of this in Sipunculus and others, and in Bonellia it has many openings into the cœloma. The tentacles of Sipunculus also act as breathing organs. There are certain ventral ciliated pouches (often four) homologous with the segmental organs of Annelids. In Echiurus all the four may be utilised as excretory ducts for the sex-organs. In Sternaspis, one pair only is connected therewith, the others containing a yellow material (urinary ?) Thalassema has only one pair existing corresponding to the former pair in Sternaspis; these open inwards by fine spiral canals. In Sipunculus there is one pair representing the latter pair in Sternaspis, and non-sexual. In Bonellia there is only one, forming a funnel-shaped uterus, and representing the right (?) of the sexual pair of Sternaspis.

The males are fewer than the females, often dimorphic (in Bonellia as a planaria-like form, living in the female sexual organs, *Kowalewsky*). The sexual organs are string-like, simple or in pairs (or a ciliated furrow on the intestine Sipunculus, *Peters*), dehiscing into the body cavity. A few are hermaphrodite

(Sipunculus, *Keferstein*). In Bonellia the eggs are developed in a longitudinal, medio-ventral fold.

The embryos are free-swimming, ciliated, with a ciliary girdle and an anterior mouth dorsally overlapped by a bilobate upper lip; ventrally, there is either a single lower lip or several ciliated processes (five in Phascolosoma minutum) the homologues of the trochal discs of Rotifera. These in Sipunculus

Fig. 25.



A, larva of Phascolosoma; *c*, upper lip; *u*, lower lip; *i*, intestine; *m*, mouth; B and C, mollusc larvæ.

develop into the tentacles. Similar lobes are not confined to Gephyrean larvæ, but reach their greatest development in the form Actinotrocha (probably the larva of the Chætopod Phoronis). The metamorphoses in development resemble those of the Echinodermal larvæ, as only part of the larva is concerned in the development of the adult.

They are divisible into two orders:—

1. Inermia—bristles and vascular system, none. Family 1. Sipunculidæ—cylindrical, with the mouth at the tip of the retractile proboscis surrounded with tentacles, often with

hooks; intestine usually spiral; anus dorsal; teeth none; skin netted with anastomosing muscle fibres (Sipunculus), or papillose, with cylindrical (Phascolosoma), or clustered (Dendrostomum) tentacles. Family 2. Aspidosiphonidæ—with two dermal shields beside the proboscis, and a posterior anus, ex. Aspidosiphon, Diesingia. Family 3. Priapulidæ—proboscis retractile, ribbed; tentacles none; anus posterior; tail bearing a tuft of hollow, pouch-like processes, and with a pore into the body cavity (absent in Halicryptus); the processes are thread-like in ten long rows in Lacazia. Anoplosomatum has cnidæ.

Order 2. Armata—bristled, with a developed vascular system. Family 4. Thalassemidæ—cylindrical or fusiform, with a non-retractile proboscis above the mouth; anus posterior; excretory organs opening into the intestine; proboscis short, undivided (Echiurus), or long, single (Thalassema), or forked (Bonellia), or absent, but a tubularly protrusible mouth instead (Ancistropus). Family 5. Sternaspideæ—ringed; abdomen flat, with a posterior horny shield, bristled round its edge; several girdles of bristles anteriorly; anus dorsal, subterminal, ending in a retractile papilla, with simple tubular threads beside it, ex. Sternaspis. Family 6. Chætodermidæ—surface beset with spines; gills 2, branched; proboscis retractile.

CHAPTER XXVIII.

CLASS 6. ROTATORIA (*Ehrenberg*).

MICROSCOPIC,* diœcious, aquatic, smooth, or slightly annulated animals. The rings are most distinct when the cuticle is not fully chitinized, and are often six, equal or unequal; but there is no trace of visceral re-

* $\frac{1}{200}$ – $\frac{1}{50}$" long.

petition. The surface may be naked or loricated, the lorica being either closely applied or as a loose sheath. At the anterior end lie one or more ciliated, lobate discs (homologous with the anterior ciliary zone of the larvæ of Echinodermata, Gephyrea, &c.), the motion of whose (usually double) rows of cilia gives the appearance of rotating wheels. Between the cilia are long, stiff bristles, and in Notommata centrura a cluster of such bristles lies in the centre of the body. Beside these *trochal discs* there is often a ciliated, frontal lobe (calcar or antenna, double in Melicerta), and there may be a ciliated, dorso-ventral groove on the surface. The dermis is of finely granular protoplasm, with a layer of round cells like the parenchyma cells of Turbellarians. Under this is an interrupted muscular layer of circular and longitudinal, smooth or striped fibres, often divided into bands, which may be specialized for the contraction of the body (which they sometimes draw in like a telescope), and retraction of the trochal disc.

There is one cervical nerve-ganglion, often in symmetrical halves, lying on, not around, the pharynx, giving off branches to the eyes and bristles, as well as lateral body-filaments. The eyes are one or two, red, placed on the neck or forehead; when only one there is rarely, when two there are usually, lenses and nerves connected therewith. Some have eyes in the embryonic, and lose them in the adult, state. Touch-bristles may be placed around the frontal lobes or trochal discs, and one or two conical or cylindrical, hair-beset tentacles may be placed on the neck. On the ganglion lies a sac containing a white, chalky matter, with, in a few cases, a duct apparently opening

anteriorly (excretory or auditory ?). Beside it there is occasionally a closed vesicle containing neither solid matter nor clear cells.

The mouth is ventral, only anterior and terminal in Floscularia and Stephanoceros; it opens into a muscular, often bulbous, non-ciliated pharynx, containing the horizontally acting, semi-lunar, or horn-like jaws. These consist of two parts: a lower jaw (incus) made of a fulcrum and two movable rami, and an upper jaw (malleus) made of a handle and a toothed blade or uncus. Muscles are attached to chitinous ridges on these. Sometimes a reserve pair of jaws lies beside the functional pair. The œsophagus is short, the stomach large, ciliated, lined by coloured hepatic cells, and receiving the secretion of a pair of rounded (pancreatic ?) glands; it may be blind, with ciliated cardiac cæca, or may end in a straight intestine with a dorsal anus. There is no circulatory nor respiratory apparatus; the clear or faintly reddish chyle moves freely in the body cavity. The water-vascular system, well marked in Limnias and Floscularia, consists of two long, often convoluted, canals, with cellular, ciliated walls, and short side branches or ovate vesicles, each with a single, central, basal filament. These have tubular or funnel-shaped openings into the body cavity. The two stems unite in a contractile vesicle, ending in the cloaca, or where there is no cloaca, opening directly behind. In embryos there exists in front of the cloaca a cellular organ, disappearing in after development (primitive kidney of *Leydig ?*)

The hinder end is elongated into a short or long, closely ringed or clearly jointed tail, which may be either a trace of metameral growth or made of two

fused parapodia. A few are sessile, tube-dwellers. The tails of others contain glandular tissue, and may end in a forceps of two blades for holding to foreign bodies. Some have long, bristled, swimming feet, three, six, or more (Triarthra, Hexarthra, Polyarthra). Pedalion has beside its two trochal discs, two median dorsal, two median ventral, two right lateral, and two left lateral appendages (imperfectly jointed ?) like those of Dinocharis, and moved by striped muscle; it has also two caudal ciliated lappets.

The sexes are dimorphic, the males being few, small, with no digestive organs except a rudimental pharynx, but with a water-vascular system. The azygos, saccular testis appears early in the embryonic male, and the end of the vas deferens is protrusible as a penis. The male may differ, even in shape of its trochal discs, from the female. The females have a roundish or crescentic ovary, an oviduct opening dorsally into the cloaca, when such exists. The eggs are of two kinds, thin-shelled in summer; but as no males are found at the time of their production, they constitute an example of parthenogenesis. From some of these eggs males develop, but they are always vastly fewer than the females. The winter eggs are hard, and often rough-shelled. The eggs have no primitive streak, and develop slowly. The embryos are directly developed, varying only in the growth or disappearance of organs. Floscularia has a worm-like larva, with a ciliary zone (*Weisse*).

There are about 215, mostly freshwater, species, some of which bear drying, and revivify on moistening.

Order 1. Gasterodela*—body sacciform, with neither

* Some make an order Gastrotricha for Ichthydium, Chætonotus, &c. Taphrocampa having a chewing apparatus, joins this to the true Rotifers.

lorica nor intestine. In Asplanchna there is an entire trochal disc and toothed jaws. The male has two large and two small pairs of limbs, but no muscles. Ascomorpha has no water-vascular system, and rudimental, toothless jaws. Some species, otherwise undistinguishable from Notommata, are also aproctous (N. myrmeleo).

Order 2. Holotrocha—proctuchous, disc entire, rounded, including the families—1. Ptyguridæ—only the post-abdomen segmented; disc circular, with one (Ptygura) or two crowns of cilia (Diplotrocha). 2. Œcistidæ—tail long; disc round or elliptical; eyes present in the embryo, persisting or vanishing (Œcistes); body in cylindrical, yellow thecæ, fastened to the base, single (Œcistes), or in free colonies (Conochilus).

Order 3. Schizotrocha—proctuchous, trochal disc lobed, notched, or divided. 1. Megalotrochidæ—deeply notched; thecæ none; umbrella-shaped, free, and possessing eyes when young, but the adults are sessile and blind. 2. Floscularidæ—disc 2–4 lobed, or with 5-6 tentacles (Stephanoceros), sometimes with two proboscides and a tubular lorica beset with lenticular bodies (Melicerta). 3, Hydatinidæ—unsheathed; disc many-lobed. Pleurotrocha has one tooth and no eyes. Hydatina has a short foot, no eyes, and several teeth. Notommata has a nuchal eye. Hexarthra and Polyarthra have limb-like processes. Diglena has two frontal eyes. Triophthalmus has three eyes. 4. Euchlanidæ—like the last, but loricated. Euchlanis has one eye-speck and a short jointed foot. Salpina is pointed at each end, has one eye and a dorsal groove. Metopidia has two eyes, and Lepadella none.

Order 4. Zygotrocha—two, simple, trochal discs, often with a frontal lobe between them. Family 1. Philodinidæ—naked, with a long divided tail; jaws two, crescentic, with two teeth on each; often viviparous, with two frontal (Rotifer) or nuchal eyes (Philodina, found in Alpine snows), or none (Callidina). 2. Scaridinidæ—foot with long joints, often with long bristles; not retractile; skin soft (Scaridium), or hard (Dinocharis). 3. Brachionidæ—loricated, completely enveloped behind (Anuræa), or with the foot passing through

a hole in the lorica, which may be sculptured, or elongated into horns in front; eyes none (Noteus), two (Pterodina), or one four-angled nuchal (Brachionus). Arthracanthus has long, pointed, retroverted lorical spines. 4. Perosotrocha—worm-like, with a rudimental trochal disc. Albertia, parasitic in earth-worms, has only a ciliated oral edge. Lindia, also parasitic, is non-ciliated, with two club-like head processes, and a short bifid foot. Apsilus is a non-segmented, thick-skinned form, found on Nymphæa leaves. The young females are ciliated, and with eyes; the males retain these, but adult females lose them. Balatro is also non-ciliated.

CHAPTER XXIX.

CLASS 7.—HIRUDINEA.

MOSTLY aquatic, ecto-, rarely endo-parasites,* consisting of a chain of homonomous metameres, called *zonites*, usually ringed on the surface, but the rings are surface markings, 3–5 being on each zonite. A sucking disc exists at one or both ends, the hinder one usually large, the anterior small, often spoon-shaped, sometimes shielding the head. Secondary lateral suckers exist on the feet of Branchellion and on the head of Branchiobdella. The cuticle is smooth, rarely warted (Pontobdella), bristled only in Acanthobdella, ciliated in Malacobdella. The dermis is of loose, round, or angular connective cells, often with stellate or branched pigment cells (Piscicola), and in it are two kinds of unicellular glands, a superficial set pouring out mucus, either universally distributed or

* Macrobdella, from Valdivia, is the giant of the order, measuring 2·5'.

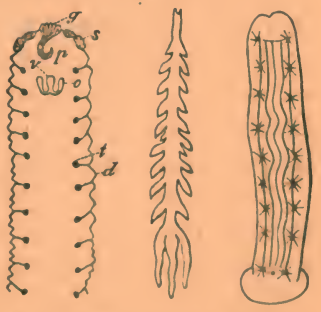
only at the mouth and sucker (Piscicola, Branchiobdella), and a deeper, secreting a chitinous material which constitutes the "cocoons" for the eggs. These are only developed during oviposition. There are three laminæ of unstriped muscular fibres, circular, radiating, or sagittal and longitudinal, having a rich development of connective tissue between the fibres. Some of the second set stretch laterally from the dorsal to the ventral surface; of these radial fibres, mixed with connective tissue, the suckers chiefly consist. There is rarely a body cavity (Branchiobdella), but such may exist in the embryo, though absent in the adult.

Fig. 26.

Transverse section of Leech; *dv*, dorsal vessel; *i*, digestive canal; *m*, muscular wall; *vn*, ventral nerve cord; *e*, segmental organ; *p*, parenchyma; *lv*, lateral vessel.

The nervous system consists of a ventral cord dilated into ganglia at regular intervals (twenty-three in the common leech, twenty-one in Clepsine, *Baudelot*). In the young these are two lateral cords, which remain apart in Malacobdella (Fig. 27, C), but approximate and often fuse in others. The anterior and posterior ganglia are the largest, and are knotted; four are fused anteriorly in Clepsine; seven in Hirudo; seven posteriorly in Clepsine. Above the pharynx,

Fig. 27.



A, generative organ of Leech; *g*, gland; *s*, seminal vesicle; *p*, penis; *t*, testis; *d*, vas deferens; *o*, ovaries; *v*, uterus; B, digestive canal of Leech, showing cæca; C, nervous system of Malacobdella.

branches of the first ventral ganglion unite to form an upper, lobate, pharyngeal ganglion, made of several little clumps of nerve cells. No branches arise from the inter-ganglionic cords, but the twigs from the ganglia are numerous and symmetrical. An indistinct third central cord may exist in some parts of the nerve axis. The neurilemma contains muscle-cells, and is double, the layers being separated by pigment cells. A single nerve lies beneath the intestine, sending branches to the cæca. It has ganglion cells along its whole course. Curious sense-organs exist in the form of "cup-like organs," most abundant on the head, and hinder, but not hindmost, rings. Each of these is a little depression covered by clear cells, and having a nerve twig terminating in the centre (Hirudo, Hæmopsis, Nephelis, &c). These resemble the organs of *Semper* in Gephyrea, or, more remotely, the lateral line organs of fishes. Some of these have pigment flecks, and are then considered eyes, but they are possibly only general sense-organs; of these there may be two (Clepsine), four (Piscicola), eight or ten (Hirudo). In the common leech they are in two series on the 1–3rd and 5–8th rings. In it, also, a row of white spots on the horizon of the eyes marks the division into zonites. Limbs are absent, or as flat lateral appendages (Branchellion, Branchiobdella).

The mouth is in or below the anterior sucker, leading into a muscular pharynx, sometimes protrusible as a proboscis, which has then special retractor muscles, and no teeth. Others have 2–3 plates of calcified chitin (jaws), with serrated edges (teeth), or unarmed. Brown, oral, salivary cells may line the pharynx, opening outwards like the glands of Trematodes. The

œsophagus may be long (Hæmenteria), or short, but the stomach is long, with alternate dilatations and contractions (Pontobdella), or with lateral cæca; of these Clepsine has six, Hirudo nine, Piscicola ten, Aulacostomum only two. These may be branched as in Clepsine, reminding one of a dendrocœlous Turbellarian. The pylorus is surrounded by a sphincter, and the straight intestine runs often between the two hindmost cæca, which are longest, the only ones present in Aulacostomum. The intestine may also have cæca (Clepsine) and a pre-anal dilatation (Piscicola). The anus is dorsal above the hinder sucker.

The circulatory system contains often red blood, the colour residing in the fluid, seldom in the corpuscles. In most, the blood flows in the nearly obliterated body cavity which here exists as a system of sinuses. These may form two lateral pulsating vessels, and a median sinus divided by the viscera into dorsal and ventral vessels, which in Clepsine and Piscicola have valves, but these around the pharynx are continuous as a vascular ring, and freely anastomosing; lacunary branches from these vessels complicate their relations; some of these are contractile spaces in Nephelis. These lacunæ permeate freely the spongy dermis and muscular layers. Respiration is dermal, and the lateral vascular organs in Branchellion and Ozobranchus may also be for breathing purposes.

The excretory organs are tubes with glandular walls, symmetrically arranged along the ventral aspect, varying from two (Branchiobdella) to seventeen (Hirudo), either closed internally, or opening within by a ciliated, funnel-shaped orifice, while the outer opening may be on a lateral wart. A primitive set of

three pairs of these "segmental" organs develop, separate from the primitive streak, on the hinder half of the abdomen. These never open inwards, and vanish when the permanent segmental organs appear. Sometimes the wide, pouch-like forms open internally into plexiform canals, formed of an aggregate of large cells with branching spaces between them. These are not sexual in function.

Leeches are mostly hermaphrodite, but not self-impregnating. The sex-organs resemble those of Trematodes, as a symmetrical pair of each kind exists, opening ventrally. The testes are either two simple pouches (Pontobdella), or else a row of glomeruli* (Fig. 27, A, *t*) on each side, whose efferent ducts unite in two lateral longitudinal vasa deferentia, dilating near their end into seminal vesicles, whose ducts unite; an accessory gland (sometimes acinose, Clepsine) secretes an albuminous matter, which unites the spermatozoa into clumps (spermaphores). The end of the duct may be protrusible as a penis, or there may be a special penis sometimes armed with recurved hooks (Branchiobdella). The male organs open in front of the female. In Branchiobdella the sixth segment wall secretes the semen, which escapes by two canals to a glandular pouch at the base of the penis. There are two ovaries and oviducts, often with an albumen gland at their confluence into a dilated sac (uterus). The eggs are enclosed in a smooth or rough capsule or cocoon, surrounded by fluid albumen, within which the embryo begins to creep, developing a pharynx; then a primitive streak forms, on which the ventral nerve cord

* Five pair, Ichthyobdella, Branchellion; 6, Piscicola; 8, Hæmopsis; 9, Hirudo; 12, Aulacostoma.

develops, each ganglion being primitively double; later appear the sex-organs and a series of solid oblique cell buildings, which, becoming hollowed, form the segmental organs. In some (Piscicola) the ova are cells detached from the wall of the ovary; in others (Nephelis, Clepsine, Hirudo) a thin, tortuous protoplasmic rachis forms in the ovary, from which the eggs bud as grape-like masses, and become detached. Fossil leeches have been found in the Lithographic slate.

The forty genera may be grouped in a single order, containing six families:—

1. Malacobdellidæ—diœcious, soft, flattened, ciliated, not ringed; pharynx protrusible; anterior sucker none; the colourless blood flows in two lateral and one dorsal vessel; two chains of lateral ganglia (Fig. 27, C), the terminal ones of which are united by long commissures; parasitic on Mollusca; in some respects allied to Amphiptyches. 2. Acanthobdellidæ—hermaphrodite, spindle-shaped, flat; anterior end with a bundle of bristles at each side; anus in the posterior sucker. 3. Histriobdellidæ—diœcious; hinder part split into two movable processes; head with tentacle-like processes; two horny jaws in the pharynx, and a simple intestine; they live on lobsters' eggs. 4. Branchiobdellidæ—monœcious, round, unequally segmented, papillose; head-lobe separated from the oral sucker; two jaws, one dorsal and one ventral, in the pharynx; anus over the posterior sucker; genital opening medio-ventral. Branchiobdella is eyeless, and lives on the gills of crabs. Temnocephalus has a lobate head and two eyes. 5. Clepsinidæ—monœcious, short, flat, gradually enlarged in front, with three rings in each metamere; anterior sucker present or absent, with no jaws and a protrusible pharynx; anus over the hinder sucker; eyes present; parasitic on Molluscs, Fish, and Frogs. Clepsine bioculata has the generative openings between the 25th–6th and the 27th–8th rings; it carries its young fastened

under its abdomen for a while. Hæmenteria has a mouth in front, not in the middle, of the sucker, in a protrusible proboscis; both genital openings are on a common wart; the glands about the neck pour out an irritating secretion, which cause urticaria in the human subject. Piscicola has a linear body with wide anterior genital openings, and is not capable of rolling itself up. 6. Hirudinidæ—hermaphrodite; narrowed in front and behind; four or five rings on each metamere; an anterior sucker present; pharynx slightly protrusible, with three toothed jaws; anus over the hinder sucker. Pontobdella has six eyes, and both suckers are on narrowed ends; the body warted, not ringed; they are ecto-parasitic on Fishes. Branchellion has, on each edge, twenty-six leaf-like processes; they are not ringed, and have 4–8 eyes; living on the gills of the Turbot and Torpedo, &c. Ichthyobdella is elongated, obsoletely ribbed, with 4–8 ocelli and sub-elliptic suckers. Hæmopsis has ten eyes and jaws as hardened folds of the pharynx. These do much mischief, as, when young, they are taken in by cattle with the water which they drink, and attach themselves to the pharynx, and even may enter the wind-pipe. Trochetia has toothless jaws, and genital openings between the 32–3 and 37–8 rings. Aulacostomum (Horse-leeches) are cylindrical, with the hinder lip of sucker obliterated; cæca small, or none; intestine wide; anus large; genital openings in males between 24–5 rings, in females 29–30. Hirudo has the first disc ringed, not separated by a constriction from the flattened body; eyes 10; jaws 3, semilunar, with 30–100 teeth, and 100 rings on the body. H. medicinalis, the German leech, is dark green, with black spots below. H. officinalis, the Hungarian leech, is olive green, without spots below; each jaw has 70–90 teeth each, with two roots. The sex-openings are as in Aulacostomum. They take three years to become sexually mature, and live 18–20 years. The cocoons are laid in summer and winter, and the young embryo begins to creep in 4–6 weeks. A few retain the cocoons attached to their bodies, thus appearing viviparous.

The thirst for blood in leeches can be increased by putting them in a mixture of wine and water, or one part of vinegar

and eight of water. Trachelobdella has no ocelli, and a round retractile neck (found on Gobius Capito). Bdella has a deep grove on the under side of the fore lip. Podobdella is elliptic, closely ringed, without eyes or teeth, and with a stalked sucker. Pinacobdella has an elongate body, with seventeen dorsal scutella and no eyes. Typhlobdella sub-lanceolate, with 81–93 rings, three jaws, no eyes; it inhabits the subterranean waters of the Baradla cave at Aggtelek, Hungary. Its orifices are as in Hirudo.

CLASS 8. ONYCHOPHORA (*Grube*).—One genus (Peripatus) with an elongated, cylindrical body of several metameres, head lobes and mouth segments united, and with two frontal feelers and two eyes. The mouth is very shortly protrusible, with two parallel, hook-like teeth. The pharynx is short, divided into a wide anterior and a narrower posterior part. The stomach forms a simple tube, ending in a short narrow intestine. There is a soft epidermis, a connective dermis, three muscular layers as in leeches, and no surface bristles; but each of the down-directed feet bears a single, double, or multiple chitinous claw. The vascular system consists of a single dorsal stem. Two lateral canals exist imbedded in the muscular laminæ, which may also be vessel stems, but they have a glandular lining (*Grube*). No other excretory organs are described. The nerve system consists of a pair of closely united, large ganglia above the pharynx, which send branches on each side of the tube to unite below. Two diverging, ventro-lateral cords arise here, which unite at the end, and the two cords (which are coated with nerve cells) are joined by many fine commissural threads. There are six single branches from the cord in each metamere, but there are no special ganglionic differentiations in its course.

They are monœcious, myriapod-like, and live in damp earth. P. juliformis, &c., inhabit the Antilles. P. Cayennensis and Chilensis, South America, others are found at the Cape of Good Hope. *Ehlers* refers these to Arthropoda, *Van Beneden* to Cotylidæ. *Schneider* places them beside Hirudinea.

CHAPTER XXX.

PROVINCE 2.—DEUTEROSTOMATA.

THIS province includes two sub-provinces, differing according to the method of the formation of the cœloma. The first of these, Enterocœla, includes those in which the body cavity is formed as an outgrowth from the digestive sac, and includes two classes.

CLASS 9. CHÆTOGNATHA (*Leuckart*)—free, marine, monœcious, cylindrical forms, $\frac{1}{2}''$ – $1''$ in length, divided into a head, body and tail; the last is margined by a striated fin,* an expansion of the cellular cuticle, and one or two pair of similar fins may lie farther forward. The surface is often bristled, and in Sagitta draco a lateral bundle of these acts as a fin. The muscular fibres are striped, in four longitudinal bundles, separated by dorsal-ventral and lateral lines. The head has 4–6 sets of pre-oral setæ, and on each side of the slit-like ventral mouth a lateral set of prehensile hook-like bristles.

* The fins seem to be bristles united by a cuticle. The bristles are brittle, arising in follicles.

The intestine is straight, attached medio-dorsally by a longitudinal band to the body wall, medio-ventrally by interrupted mesenteric threads, traversing which, close to the ganglion, is a vessel. The anus is ventral, near the hollow tail, which is divided by a partition, and in which spermatozoa form from protoplasmic masses detached from its walls, and escape by lateral slits, to which sometimes seminal vesicles are appended. There is a saccular ovary on each side of the intestine, opening beside the anus. An oval, ventral nerve-ganglion (= the cephalic ganglion of Nematodes) sends backwards a pair of lateral branches, and forwards another pair which unite pre-orally in a hexagonal ganglion. This sends off lateral branches to the conical tentacles when they exist (S. cephaloptera), and two anterior branches to the pair of eyes, which consist of radially arranged crystal cones on a nervous layer and mass of pigment.

Sometimes a dorsal, wheel-like disc exists, placed like a saddle. The non-ciliated embryos are directly developed, the egg passing through a gastrula stage. The one genus Sagitta is found in the Mediterranean and Atlantic. Chætosoma is probably one of its nearest allies. They have been regarded as Vertebrates (*Meissner*), or as Molluscs (*Forbes*).

CLASS 10. ENTEROPNEUSTI (*Gegenbaur*)—worm-like, brittle, contractile, diœcious animals, flattened, except at a collar-like swelling in front, and consisting of two, lateral, flattened parts, and a middle annulated portion showing traces of metameric growth. The finely ciliated, protoplasmic cutis secretes much mucus by its unicellular glands. The muscular coat is strong, the two, lateral, longitudinal bundles of fibres

not continuous mesially above or below; the circular fibres are stronger below. Anteriorly there is a hollow proboscis (sipho) for boring in the sand, with a round opening at its free end and a triangular one below. This is separate from the digestive canal, and being near to the pharyngeal ganglion is probably a sense-organ like the grooves of Nemerteans. The mouth is large; the intestine, for the most part fused with the body wall, has lateral hepatic cæca containing a greenish fluid, is often full of sand, and has a terminal anus.

The digestive canal in front bears a curious respiratory organ, supported on a basket-work of homogeneous cuticular (chitinoid ?) rods, which in arrangement and genesis resemble the branchial skeleton of Amphioxus. Between these gill arches are vertical slits (like those of a Tunicate or of Amphioxus) for the exit of the water which, entering by the mouth, bathes the vascular, ciliated, branchial membrane stretched on this framework. Each rod consists of three vertical plates, joined by transverse bands, and they are in contact at their outer end. These arches only surround the dorsal half of this region of the intestine, and the incurving of the lower ends of the arches constricts the cavity so as to make it, in vertical section, somewhat resemble the figure 8.

The intestinal wall within exhibits two ciliated furrows, from which branching grooves pass in several directions, forming a ciliated network. The ovaries are red, the testes white, lying in the lateral parts of the body, and shining through the skin. There are usually four series of sex-glands. The embryos are girdled by a single crown of cilia (*Mecznikoff*), and

early become constricted into an acorn-like anterior part, becoming the proboscis, and an oval body. There are in the adult four large vascular trunks, dorsal, ventral, and two lateral; the first carries blood from behind forwards, and divides at the gills into four branches, of which one enters the respiratory organ. There is one genus, Balanoglossus, whose three species inhabit the Adriatic and the Indian Ocean. The larva has been often confounded with the pseudembryos of Echinodermata, and is named Tornaria.

CHAPTER XXXI.

SUB-PROVINCE 2.—SCHIZOCŒLA.

CLASS 11. CHÆTOPODA (*Van Beneden*).—The single class of this sub-province includes the Deuterostome worms whose cœloma is formed by a splitting of the germinal layers. They are cylindrical or flattened, of several (2–400) metameres or *zonites*.* The first (prostomium), second (peristomium), and last are heteronomous, the others homonomous.† Some secrete a cuticular or calcareous tube, or agglutinate sand into a case. Each zonite bears bristles, rarely scattered over the surface, usually in diverging bundles, often around a central *acicula* or seated on a *torus*, and

* Echinoderes and Turbanella are intermediate between the simple and truly jointed forms.

† Or some central zonites heteronomous from the development of the sex-organs.

raised on unjointed, movable side-processes of the body wall (parapodia*). These bristles are chitinous, striated, full of protoplasm, rarely hollow, calcareous (Euphrosyne); they arise in follicles, and muscular fibres are attached to their roots. When the cuticle is hard the young bristles have often deciduous points for piercing their way through the surface. There are variously arranged dermal appendages or cirri, often shield-like (*elytrae*) and iridescent, or groups of long pillared suckers, as in Pelogenia, somewhat like the ambulacra of an Echinoderm. Nettle-cells, or rod-like bodies resembling them, are found in the tentacles and cirri of Spionidæ, Chætopteridæ, Ariciidæ, &c. The cirri on the prostomium are thread-like (*antennæ*), or thick and fleshy (*palpi*). Those of the peristomium are called tentacles. The tail has generally two long cirri.

The cuticle is of many layers, soft and thin at the junctions of the zonites. The whole surface is rarely ciliated (Ichthydiidæ). Polyophthalmus and Prionognathus have cilia in bundles. Partial ciliation is common, especially on the appendages (Capitella has two ciliated head-lobes). The cuticular laminæ are often striated, the superficial and deep striæ crossing at angles of 70° or 90°. Through these layers pass pore canals, which may open on wart-like eminences. The connective cutis is thinner than the cuticle, and contains pigment cells, bacillar corpuscles, and glands, of four kinds—uni-cellular (in Lumbrici); mucous, with an epithelial lining, often lobate and numerous, either over the whole surface, along the line of the cirri, or along the notopodia only (Sphærodorum); tubular glands in Nereids secrete globular concretions; calcigerous dorsal glands in Serpulæ, which

* These are rarely bristle-less, never modified into jaws. In higher forms there are two pair on each zonite: two dorsal, one on each side, called Notopodia, and two ventral, Neuropodia.

secrete the tube in which the worm lives. The mucous glands of the clitellum in earthworms secrete a chitinous material, like that of the cocoon glands of leeches. The sub-dermal layer may be nucleated protoplasm (Chætonotus), simple, parallel, non-nucleated fibres, unstriped or striped, longitudinal and circular; sometimes each fibre has a cortical and a medullary layer (Nephthys). The longitudinal fibres are divided into tracts by dorsal, ventral, and lateral lines. Oblique fibres cross from the neuropodia to the notopodia. Deep processes of this layer form septa, dividing the body cavity into metameric chambers, except at the front end, where the first few segments have no partitions. In Polyophthalmus, two longitudinal septa, below and free from the digestive tube, attached to the medio-ventral and lateral lines, cut off two long chambers from the general body cavity. Direct openings into the body cavity exist in Lumbricus and Enchytraeus.

The mouth opens on the peristome, and may have a protrusible, cylindrical, club-like or leaf-like epipharynx or proboscis, with a boring spine in some Syllidæ. The mouth may have 1–5 toothed jaws, often with hooks at the base, and the peristome may have papillæ or tubercles. The œsophagus has sometimes simple salivary glands, and may dilate into a muscular proventriculus, in which may be chitinous teeth (Gnathosyllis) and glands. The digestive canal is rarely divided into stomach and intestine, coiled in Chloræma and Pherusia. It often has lateral cæca in each metamere, simple or branched, with terminal glandular pouches (Aphrodite). The intestine has, as in Gephyrea, epithelial, basement, and muscular coats (the last transversely striped in Phreoryctes). The middle tract of the intestine may have a lining of yellow or green hepatic cells, but has never separate glands. In the lowest part, gland cells containing

little concretions may exist. The anus is terminal, or dorsally sub-terminal.

The vascular system may be absent (Glyceria, Tomopteris,* &c.) or rudimental. Polygordius has a single dorsal vessel giving off cæcal transverse branches. Most worms have four longitudinal canals—1, a pulsating dorsal vessel, double in Nephthys, carrying blood from behind forwards, lying in a cellular mass on the digestive canal; 2, a ventral vessel, rarely pulsating (Clymene, Maldania), or double (Eunice)†; 3, two lateral symmetrical trunks, usually accompanying the lateral nerves, rarely pulsating (Protula Dysteri). These stems are joined by terminal and metameric cross branches, some of which may be dilated, acting as simple hearts (Sænurus, &c., Fig. 28); these give off parietal and visceral branches, some of which end cæcally, but most others have a closed or lacunary communication between the arterial and venous branches. To these branches contractile cæca may be appended (Lumbriculus variegatus), which may lie in contact with the ducts of the segmental organs. In the cephalobranchiate forms the dorsal vessel dilates into a pulsating sac (branchial heart) on the pharynx, sending off gill-vessels, which return to the ventral stem. In Polyophthalmus the dorsal vessel divides into lacunary

Fig. 28.

Circulatory vessels of Sænuris variegata, showing the dorsal and ventral vessels, the transverse anastomoses, and the cardiac dilatations of one of the latter.

* In these the perienteric corpusculated fluid circulates in the body cavity, moved by the peritoneal cilia.

† There may be two dorsal and two ventral vessels in Hermella.

capillaries on the intestine. The blood may be colorless, with colored corpuscles (Glyceria, Phoronis, Dujardiniæ), or more commonly is a yellow, green, red, or blue serum with colorless corpuscles. The color is often dissimilar in allied species.

Respiration may take place by the surface, by the water admitted into the perivisceral cavity, or by gills which may be modified, filiform cirri, over or under the parapodia, or dermal, ciliated, comb-like, pinnate or branched processes, into which often pouches of the body cavity enter, attached to the notopodia. In the tube-dwellers there are long contractile threads in bundles, or spirals, or fans, or tree-like, with a cartilaginous axis of support (Sabella). Some of these cirri may lose their respiratory functions, become club-like, and act as opercula to the tube. This operculum may have a calcareous, terminal disc (Serpula), or it may be dilated into a brood-pouch for the young (Spirorbis). In Fabricia, a temporary tube-dweller, the operculum retrogrades into a simple tentacle. The gills contain either simple cæcal diverticula from the transverse communicating vessels, or they may have separate inferent and efferent vessels. Colobranchus has eight oval, ciliated (respiratory ?) laminæ around the anus, and the lower end of the intestine is also ciliated. In Hesione, air bubbles have been seen emitted both by the mouth and anus. In some Syllidæ the periodic taking in and expulsion of water from the intestine has been noticed.

Each metamere has usually a pair of symmetrical excretory (*segmental*) organs, often acting as ducts for the sex-glands. These may be simple mucous pouches in Tubifex, Nais, &c., larger and

tortuous in Lumbricus, &c., having an internal funnel- or rosette-like opening into the body cavity, followed by a straight or coiled glandular portion, and a small narrow outer orifice, often in the next metamere to that wherein is the funnel. The ciliated canal below the intestine in Protula may also be an excretory organ.

The nervous system consists of a large double pre-oral ganglion, each part often of 2-4 knots, sending branches to the eyes and oral cirri. Its two components may be close together (Enchytræus), or separated laterally (Aonis). Two lateral branches form a ring around the pharynx, and unite below to form two symmetrical chains of ventral ganglia, stretching backwards, and giving off lateral branches. These chains are remote from each other, and joined by transverse commissures in the embryo and in adult Serpulæ, &c. In other worms they approach in the course of growth, and may coalesce into one cord (anterior end of Terebella), in the centre of which runs a thick distinct band of nerve tissue. The anterior ganglia may be unequal (Clymene), and are usually largest. Sometimes on each metameric branch at the base of the parapodia little ganglia exist, also united by longitudinal commissures (Pleione).

A special nerve system, homologous to the azygos nerve of the leech, and analogous to the sympathetic, lies on the intestine, connected to the pre-oral ganglia on the œsophagus, and when there is an epipharynx sending branches to it, it expands backwards on the intestinal wall, having special ganglia of its own, and differs in texture from the ordinary systemic nerves.

Sense organs are widely distributed. The cirri

of the anterior segments are sensitive, and may be jointed. The ciliated grooves in Polygordius resemble those of Nemerteans. The eyes, usually on the prostomium, consist of a pigment spot, a nerve, and generally a lens, often 2-3 lenses on the one pigment spot. They are rarely simple specks, usually close to the ganglion. When there are four they are rarely equal; one pair is generally large, and the other only pigment spots. Branchiomma has many eyes on its tentacles, Sabella on its gills. Each has a

Fig. 29.

A, section of body of Worm (peristomium); *a*, cuticle; *b*, dermis; *c*, *f*, dorsal and ventral muscular plates; *d*, opening of the segmental organ; *k*, cœloma; *h*, dorsal vessel; *i*, ventral vessel; *g*, intestine; *n*, sexual organ; *e*, nerve ganglion. B, section of Amphioxus. C, section of vertebrate embryo.

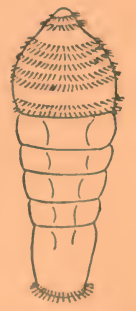
pigment spot, and diverging crystal cones on it. Eyes exist in the tail segment in Fabricia, Amphicorina, and Amphiglena. Polyophthalmus has three prostomial eyes resting on the ganglion, the middle with three, the lateral with two, crystal cones. Each succeeding metamere has also a pair of eyes sunk in its skin, and receiving a nerve from the ganglion of the segment. Myxicola has also metameric eyes. In Torrea and Alciope the eyes are large, with a retina, choroid, iris, and lens. Otocysts exist as simple transparent vesicles on the pharyngeal ring of Arenicola

and Amphiglena, with many otoliths (in Fabricia and Amphicorina with one).

The capacity of repairing injury is very great. Reproduction may occur asexually by gemmation from the penultimate segment, as in Nais, Chaetogaster, Eolosoma, Myrianida, &c. In the last, *Milne Edwards* saw a chain of six continuous, the first with ten, the second with fourteen, the third with sixteen, the fourth with eighteen, the fifth with twenty-three, the sixth with thirty joints. Of another species, *Claus* saw 12–16 new, four-jointed individuals in a chain. Detachment of some metameres, followed by the growth of a head, is a form of fission occurring in some species. Some species have asexual as well as sexual forms; the former give origin to the latter by budding. They are diœcious, except Lumbricus, Protula, Amphiglene, Spirorbis, and some Serpulæ, and often dimorphic. In Lumbricus the sex-organs are in a limited number (mostly 8–15) of zonites, the glandular layers of the integument of which are swollen dorsally and laterally, forming a saddle-like eminence (clitellum), which is separated from the lower unthickened part by a muscular ridge on each side. The ventral setæ of this region are clasping for copulation. Each has a single bristle. There are two pairs of testes, connected to which are wide saccular vesicles into which the semen passes. In each of these vesicles is a pair of funnel-like organs, ending in a vas deferens, which on each side unites with its neighbouring vessel, and passing backwards, opens at each side in the base of a bristle-like copulatory organ on the fifteenth ring. The orifices have glandular lips. The spermatozoa are short thin threads with swollen heads. The pair

of ovaries are small, behind the testes, having two wide-mouthed oviducts behind them, attached to the body wall; with these communicate round spermathecal sacs lying near the testes. The oviducts open anteriorly to the penis. In the earthworm six segments in advance of the clitellum are the copulatory, adhesive organs, which are modified, imperforate, locomotor setæ. Most other worms have no special genital ducts, but empty the sex-products through the segmental organs. The ova may form on the inner wall of the dissepiments, or of the body cavity (Tomopteris), or in 1–3* pair of ovaries, and the semen in 1–4 pair of testes. Each sex-organ has a vessel or a cellular string in its axis, from which the sperm cells or eggs bud.

Fig. 30.



Polytrochal larva of Arenicola.

The ova are either single or in clusters within capsules, cocoon-like in Lumbricus, pillared in Arenicola, with copious or no albumen (Tubifex). A few (Eunicea, Syllis, Cirrhatulus) are viviparous. Lumbricus develops directly. Most of the others have indirect development by a dissimilar larva. This has no gastræal stage, according to some observers, and may be ciliated at the extremity (Telotrochal), at one end only (Monotrochal as in Polynoë), or at both ends (Amphitrochal as in Terebella), or ciliated in the middle (Mesotrochal as in Spiochætopterus), or with many wreaths of cilia (Polytrochal as in Arenicola, Fig. 30). Lysidice has five ciliary

* Œnone diphyllidia has in the side of each ring two little grape-like ovaries, whose common oviduct opens at the base of the parapodia. Euphrosyne has symmetrical ovaries extending as winding pouches, opening at the back of the inner edge of the gills. Chloeia has lobed ovaries, each lobe a long pouch.

wreaths and a ciliated ventral surface. From these larvæ the head becomes differentiated with its two segments; then the tail, the cilia are lost, and intermediate segments form by gemmation. Spirorbis and Pileolaria have brood-pouches wherein the embryos pass their early stages of development. Some retrograde in growth, *e.g.*, many Cephalobranchs have eyes and otocysts, which are lost afterwards.

About 1500 species are known, none of which are true parasites, though some are commensals; thus the larvæ of Alciope live in Cydippe, Lepidonota cirrhulæ in the tubes of Chaetopterus insignis, Nereis fucata in shells occupied by Paguri, and a little Amphinome in Pentelasmis anatifera. They are mostly marine, littoral, a few freshwater or terricolous. They are divisible into four orders:—

1. Oligochæta (*Grube*, Scoleina, *Gegenbaur*)—mostly terrestrial or freshwater, with few (2–8) rudimental bristles in each cluster; no tentacles, gills, nor cirri; mostly hermaphrodite. This includes the following families:—1. Ichthydiidæ—unsegmented, or with segments only indicated by bristly and ciliary wreaths; head ciliated. Ichthydium is not bristled, while Dasydytes is bristle clad, with a simple truncate tail, and Chætonotus with a forked tail. Taphrocampa, allied to these, has a mastax like a rotifer. 2. Naididæ—segments few; skin thin; head lobes united, often prolonged; bristles in two rows; eggs simple, single, large; hard-shelled in Aelostoma. Aulophorus secretes a tube which it carries about; its upper bristles are hair-like, the lower stiff. Mesopachys has all the bristles hair-like. Nais has its under row of bristles fixed. 3. Enchytræidæ—bristles two-rowed, equal, awl-shaped (Enchytræus), or hook-like (Parthenope); mouth segments united; blood colorless; eggs large, singly included in capsules. 4. Tubificidæ—mouth segments united, often lengthened; skin transparent; four rows of simple (Enaxes) or forked (Saenuris) bristles; eggs large, without albumen, several in one capsule. 5. Lumbricidæ—cylindrical, many-jointed, with a clitellum (except in Helodrilus and Criodrilus); prostomium free (except in Criodrilus); skin opaque; head lobes conical; bristles hook-like, two or more rowed, or over the whole surface (Perichæta); eggs many,

with albumen, and in a common capsule; eyes none; blood red; mouth unarmed. Lumbricus, the common earthworm, has two-rowed hooked bristles, three salivary, several œsophageal glands on the thirteenth ring, and a muscular stomach behind the proventricle or crop in the fifteenth ring; it has two pair of testes and five pair of capsuligenous glands. Pontoscolex lives in the sand of the Red Sea. Phreoryctes lives in wells. Hypogæon reaches an enormous size, as does Megascolex.

2. Gymnocopa (*Grube*)—body long, flat, not sharply segmented, in front broad; parapodia only developed in front, two lobed, without bristles, but the two or four short frontal feelers and the two long tentacles are bristled; eyes two; mouth with no epipharynx nor teeth; segmental organs with a rosette-like opening; diœcious; marine. This includes one family and two genera, Tomopteris and Eschscholtzia.*

3. Notobranchiata (*Schmarda*)—gills various or rudimental, appended to the notopodia, vascular; eyes and cirri various; parapodia usually present. Family 1. Polyophthalmidæ†—small, marine, free, with few segments, no parapodia; head three-lobed, with no cirri; a protrusible unarmed epipharynx; eyes before described; they are passage forms between Naididæ and Serpulidæ. 2. Halelminthidæ—parapodia, appendages and eyes absent; body in a membranous tube, ex. Capitella. 3. Maldanidæ—long, round, unequally segmented, living in tubes in sand; prostomium flattened, with entire (Clymene) or split margin; no eyes, gills, nor feelers; parapodia bilobed; epipharynx club-shaped, often papillose (Notomastus). 4. Chætopteridæ—zonites heteronomous; body divided into three regions, living in leathery or stony tubes; gills none; head segments with three feelers; eyes 2 (Chætopterus), or none (Spiochætopterus); larva mesotrochal. 5. Halonaidæ—with no parapodia, but with appendages and eyes, ex. Dero, with caudal, branchial appendages. 6. Aphroditidæ—segments unequal, with dorsal, shield-like elytrae;

* This name is pre-occupied.

† Families 1, and 2, and 5 are made the types of a separate order Haloscolecina by *Carus*.

head-lobes developed, with a single tentacle and lateral antennæ and palpi; eyes sessile or stalked (Pontogenia, Hermione); gills small, simple; epipharynx mostly with two upper and two lower teeth and jaws; vascular system often rudimental; one central tentaculum and lateral antennæ, and sometimes palpi. Polynoë has no prostomial tubercle; eyes 4; 12–35 pair of elytrae. Gastrolepidia has ventral as well as dorsal scales. Aphrodite, the sea-mouse, has an oblong body, iridescent elytræ on the 2–4, 5–7 *** 23–25–28, &c., segments; eyes sessile, facial tubercle under the single frontal tentacle. Iphione is oblong, with two lateral head-lobes and two frontal tentacles; noto- and neuropodia united. Acoëtes has two eyes, and no facial tubercle. 7. Palmyridæ—elytræ none: each segment covered by a fan-like group of paleaceous scales; dorsal cirri alternating with tubercles; segments many (Bhawania), or few; eyes 2 (Palmyra) or 4 (Paleanotus). 8. Amphinomidæ—angular or flat; segments equal, not many; head small, usually with five tentacles; toothless; gills dorsal, comb- or tree-like; bristles hair-like, serrate, not acicular; head-lobes often compressed; prostomial caruncle may be long, each segment carrying several branched gills (Euphrosyne); the caruncle is absent, and the head-lobes small in Hipponoë, or there may be round head-lobes with frontal feelers, and two bipinnate gills on each segment remote from the feet (Chloëia), or at the point of the feet (Notopygus). The head caruncle may be heart-shaped (Amphinome), or with leaf-like lateral lobes (Hermodice). 9. Euniceidæ—rounded, long, with many metameres, flattened ventrally, living in sand-burrows; head-lobes notched in front, with 1–5 tentacles; several separate upper, and two, often united, lower jaws; parapodia simple, with acicula; gills either beside the dorsal cirri, simple, comb-shaped (Eunice, Onuphis), or spiral (Diopatria), or else absent (Lumbriconereis, Lysidice), or replaced by leaf-like dorsal cirri (Ænone, Aglaura). 10. Nereidæ—body long, with two anal cirri; head flat, small, with four eyes, two small middle and two large outer feelers; peristome with eight feelers; epipharynx protrusible, with two large horizontally movable jaws, armed with denticles; parapodia

double, with acicula, and no hair-like bristles; they may be all similar (Nereis), or some of the dorsal cirri feather-like (Dendronereis, &c.) 11. Nephthyidæ—body long, many-jointed; lateral feelers small; peristome with no cirri, but with parapodia and papillæ in place of teeth. Nephthys, the "hairy bait" of fishermen, has one anal cirrus. 12. Glyceridæ—many ringed segments; proboscis club-shaped, protrusible; bristles with acicula; gills short, or none; chylaqueous fluid colored in some by red corpuscles; vascular system none. The proboscis may have four hooked teeth with no points (Glycera), or rows of pointed teeth (Glycinde). 13. Phyllodocidæ—long, many jointed; head lobes small; feelers 4–5; eyes 2–4; epipharynx with papillæ; ventral cirri leaf-like; larvæ monotrochal; the cirri leaf-like, covering the back (Phyllodoce), or leaving it mostly uncovered (Eulalia). These genera have four pair of prostomial cirri. Eteone has two, and the leaf-like cirri do not at all cover the back. Alciope has two large, Lopadorhynchus two small, eyes. 14. Hesionidæ—few-jointed, with broad head-lobes and long peristomial tentacles; protrusible unarmed epipharynx, with no gills; oars one- (Hesione, Oxydromus) or two-branched (Ophidromus), or with an upper tubercular branch and two delicate teeth (Castalia). 15. Syllidæ—elongated; head with tentacles, often with eyes; peristome with 2–4 cirri, often united to the prostomium; pharynx not protrusible, sometimes toothed, or with a chitinous tube which bears a boring spine; oars one-branched, with two aciculate bristle-clusters; ventral cirri short, or none; blood colorless, but with colored corpuscles in Dujardinia; circulatory organs undeveloped or rudimental; the sexes are dimorphic; reproduction often by budding; there may be a metagenetic condition, the product of the development of an egg multiplying by gemmation, but itself remaining sexless (Autolytus). Oophylax and Paedophylax carry their eggs about until they develop. Gnathosyllis has pharyngeal jaws. Schmardia and Grubea have a dagger-like pharyngeal organ. 16. Leucodoridæ—segments heteronomous, a few being small; prostomium with one thick and two little feelers; peristome with two long respiratory cirri; feet two-oared, with bristles, or bristles and

hooks; most are tube-dwellers, buried in sand or fastened to stones; body transparent; eyes 2 (Disoma), or none. 17. Nerinidæ—segments homonomous; head with eyes; feelers often none; feet one- (Pygospio) or two-oared (Nerine). Spio has tongue-like gills. Colobrachus has a peculiar anal breathing organ. 18. Cirrhatulidæ—rounded, fusiform; head with no teeth, feelers, nor tentacles; oars in two series, on the lower hooks; thread-like gills on five or six anterior segments (Dodecaceræa), or on all but the first and last (Cirrhatulus). Andoninia has spindle-like blood corpuscles. 19. Ariciidæ—with no feelers nor teeth, and generally four eyes; segments short; oars two-branched. The epipharynx is leaf-like in Anthostoma, protrusible in Ephesia, which is eyeless, but not protrusible in the four-eyed Sphærodorum. 20. Opheliidæ—feelers and eyes none; zonites few; oars small, one or two only with bristles, one set of gills limited to the middle of the back (Ophelia), or on nearly every segment (Travisia); head pointed; tail papillary; body flat beneath, with (Ophelia) or without a definite "sole" (Ammotrypane). Ophelia has in its perivisceral fluid stellate bodies with immovable processes. 21. Arenicolidæ—head small, conical, with no eyes nor feelers, and a papillary proboscis; the middle segments have tree-like gills, while the front and tail segments have none; oars double, the upper bristled, the lower hooked; the larvæ are polytrochal; they burrow in sand. Arenicola, the "lug-bait," has no tail appendages. Scalibregma has anal cirri. Eumenia has gills on the anterior segments.

4. Cephalobranchiata—mostly tube dwellers, with breathing organs on the head, either as long contractile threads, or fan-like, or spiral; pinnate or comb-like lobes, and sometimes tree-like gills on the prostomium; some have dorsal cirri, likewise respiratory; no teeth nor epipharynx. 1. Pherusidæ—free, and peristome bristle-less; gills of simple threads, surrounded by a girdle of long, yellow, thick bristles; zonites not ringed; parapodia with upper linear and lower hook-like bristles; blood green; body often shaggy, with sometimes terminal suckers, whereby they adhere to foreign bodies (Chloræma Dujardinii is found adherent to Echini); intestine

coiled; stomach with a spiral appendage. Siphonostomum gelatinosum has two ciliated head-lobes. 2. Hermellidæ—tubicolous; segments heteronomous, of two or three kinds, the hinder thread-like, with no appendages; the head-lobes are fleshy, cylindrical (Sabellaria), or leaf-like, split (Centrocorone) with a circlet of yellow paleæ on the prostomial border, which acts as an operculum. The tube is built of cemented shells. 3. Terebellidæ—inhabiting soft, fragile tubes; heteronomous with two regions; head with neither paleæ nor lobes, but with large, movable, ciliated gills, serving as touch- and prehensile organs; in most there are 1–3 pair of tree-like gills on the first body-ring, sometimes with a jointed framework. Sabellides has lateral, thread-like gills; Polycirrhus none. Terebellides has the gills on an azygos medio-dorsal column. 4. Amphicteneidæ—tubicolous, heteronomous, with three body regions; prostomium united to the peristome, with a middle lobe and two bundles of thread-like gills; tail segments with imperfect rings; gills simply (Pectinaria) or complexly comb-shaped (Scalis), or elongated; anal cirri one (Scalis), or two (Amphicteis). 5. Sabellidæ—tubicolous, heteronomous, with two body regions; head-gills pinnate, in two circlets or spirals, one of which may be rudimental; some have eyes on the cirri; the tube may be temporary (Amphicorina, Fabricia) open at both ends. Heterosabella has no sheath for the body. Myxicola has two head-eyes, four tail-eyes, and forty pair of metameric eyes. Phoronis has the gills on a horseshoe-shaped lobe; body not ringed, with no parapodia; blood with red corpuscles; its larva is the form called Actinotrocha. The tube in Sabella is open only at one end, and membranous. Protula has a ventral dermal expansion. P. Dysteri is hermaphrodite. 6. Serpulidæ—tubicolous, heteronomous, with two ciliated skin folds on the front segments; the gills have a spiral basis, with one or two opercula with chitinous or calcareous discs; blood red, green, or blue; the tubes are attached to stones, &c., calcareous, worm-like (Serpula), spirally rolled (Spirorbis), or free (Ditrupa). Filograna has eyes at the base of the gills.

Chætopod worms have existed since the days of the Cambrian formation (Arenicolites, Histioderma, Helminthites), possibly since the Laurentian (Scolithus ?). Tube dwellers are found in Silurian and Carboniferous rocks.

CHAPTER XXXII.

CLASS 12.—BRYOZOA* (*Ehrenberg*).

COLONIES with tree-like, or membranous, fixed stocks (polyzoaria) supporting numerous personæ in cells†, and composed of an outer chitinous or calcareous ectocyst or cuticle, and an inner endocyst or dermis (rarely absent as in Rhabdopleura). They are rooted by a process of the ectocyst, and bear the cells for the monœcious personæ on one or two sides of the stock, or radially around it. Each cup rarely communicates with its neighbour (except in Ctenosomata, where also they have serrated mouths). They may be joined one to another, or united by cœnenchyma, and the branches joined by stolons. The ectocyst consists of indistinct epithelial cells and often of calcified, vertical, hollow fibres. The endocyst—soft, ciliated, and contractile—lines each cell, and is reflected inwards at

* This and the next are probably Epicœlous (p. 47); and should probably form a separate province. This class is also named Polyzoa (*Thompson*).

† Cristatella, which has no ectocyst, glides along snail-like. Some Selenariæ move by their enormous vibracula. Lophopus, which has a gelatinous ectocyst, is also capable of locomotion.

the cell mouth to be continuous with the outer membranous investment of the tentacles. It consists of a layer of large, irregular, connective cells with (distally) or without (proximally) a nucleated intercellular substance. Within is a layer of fine longitudinal and transverse fibres, crossing each other at right angles, and permeated by fine, netted canals containing oval corpuscles. Each polypide or persona is lodged in a cell, and possesses a crown of 8–80 ciliated, hollow, oval tentacles* (branchiules, *van Beneden*) like those of Chaetopoda, whose cavities communicate with the cœloma; each tentacle consists of an outer wall of round, often nucleated, cells, and an inner structureless layer. They are seated on a basis or *lophophore*, either horseshoe-shaped, as in all the freshwater genera, except Paludicella and Urnaria, or else circular, as in all the marine forms except Pedicellina and Rhabdopleura. The former group have a buccal shield, valve or epistome (homologous with the foot of a Mollusc) arching over the mouth, and the tentacles are often united for $\frac{1}{3}-\frac{1}{4}$ of their extent by a basal membrane forming a calyx. The epistome is not to be confounded with the operculum of the cell, an ectocystic process found in Myriozoon and Chilostomum.

Three kinds of appendages (undeveloped personæ) are found on the ectocyst of the colonies:—1. Avicularia—two-armed graspers, with a calcareous basal part, in shape somewhat like a bird's head, with a horny, sometimes serrated, beak, and a movable limb or under jaw; between these there is often a ciliated lobe. They are placed near the mouth, and open and shut rhythmically, grasping prey. Three forms are described—a. pedunculata, on a movable, often jointed, stalk; a. sessilia, with no stalk; a. immersa, sunk into a pit

* Often in multiples of four.

in the surface of the ectocyst. 2. Vibracula, consisting of an oval capsule with no basal part, ending in a long seta like the lower jaw of Avicularia. 3. Oocysts—globular marsupial cells, found in Chilostomata, receiving the eggs on extrusion.

Each persona consists of an oval sac filled with a watery, corpusculated fluid, extending into the tentacles, and in which the digestive canal floats. The mouth of this canal can be partly protruded from the cell by evagination, and can be retracted at will. The mouth is simple, projecting, contractile; its epistome, when present, is globular or pyramidal, hollow, ciliated externally, and raised by a special inner muscle. A muscular pharynx leads by a ciliated œsophagus into the non-ciliated intestine, from which a cæcal stomach depends, whose cardiac and pyloric orifices are close together above. The intestine at first widens, leads backward, and then, narrowing, opens by an anus close to the mouth, but external to the tentacles. The flexure of the digestive canal is always concave towards the nerve ganglion. The walls of the canal consist of an outer, thin layer of contractile fibre-cells, disposed circularly, and an inner of small, simple (hepatic) cells, thick, green, or brownish in the stomachs of many genera. Marine forms have often knotty thickenings of their muscle fibres. The stomach is gizzard-like in many of the Ctenostomata, and often contains chitinous teeth. In Bowerbankia it has two opposed balls of dark, radiated fibres, and is lined by small chitinous plates; in action the balls elongate and approximate, and the radiating fibres become parallel. Hislopea has a somewhat similar gizzard. There is no vascular system; the perivisceral fluid nourishes the tissues, and is renewed by osmose

through the intestinal wall. The fluid is aerated at the tentacles or body surface.

Each persona has a yellow, oval or lobed ganglion between the mouth and anus, sending two strong branches to the tentacles and two to the œsophagus, round which they make a ring (Fredericella, &c.) Below this may be a sub-oral, pharyngeal ganglion in a few cases (*Dumortier*). Serialaria and other cteno-stomatous, branched forms have a *colonial* nerve-system, taking its origin from a ganglion at the base of each branch of the stock, which unites by fine plexiform branches with the nerves of each persona. This explains the consentaneous action noticed in a colony such as Mimosella.

No special sense-organs exist, except perhaps the ciliated body near the ganglion in Pedicellina; but many colonies of freshwater forms show by their motions that they are sensitive to light. The muscular lamina is never complete, but consists of specialized bundles, which are—1st, two retractors of the lophophore; 2nd, retractors of the polypide, from the floor of the cell to the œsophagus; these lie in the axis of the pillar in Pedicellina; 3rd, two rotators of the lophophore, in the freshwater form ending in each corner of the crescentic disc; 4th, retractors of the tentacles from the lophophore, placed between each pair of tentacles, sending a branch on each side; 5th, the levator of the epistome; 6th, Parieto-vaginalis anterior, many short transverse bands from the invaginated part of the endocyst to the protrusible part; 7th, Parieto-vaginalis posterior, stronger, behind the last, to the permanently retracted part of the endocyst; 8th, Parietalis, annular body fibres, whose anterior fibres are the sphincter vaginalis. Besides these, there are radiating fibres joining the two valves of the Avicularia, and opercular muscles in Chilostomum.

The irregularly rounded testes are either seated

directly under the stomach wall or attached thereto by a funiculus or cord which passes from the stomach to the hinder wall of the body cavity. The ovary is anterior, near the top of the cell, attached to the inner surface of the endocyst, sessile, pillared, or on a special funiculus. The ova and spermatozoa pass into the body cavity, and there probably impregnation takes place. The escape of the sex products thence may be by an opening in the body wall near the anus (Alcyonella, Farrella,[1] according to *Meyer*, *van Beneden*, &c.) In Halodactylus gelatinosus, Membranipora pilosa, &c., there is a canal with a ciliated, external mouth, leading from the body cavity outwards, between the base of two tentacles, and joined to them. The embryo, after cleavage, is ciliated and hollow; soon an opening forms at one end into the hollow, thus forming an intestine; and a lophophore appears as an eminence on the floor of the cavity. It may increase by budding, even before it is perfectly developed. The locomotor embryo is pear-shaped, but soon losing its cilia, it settles down, differentiates into endocyst and ectocyst; new buds develop from the former, which, growing continuously, build up the colony, each new cell being separated by a partition from its parent. Sometimes stolons are produced from the primary polypide.

Gemmation is sometimes discontinuous, the separate gemma (statoblasts) springing from the funiculus as flat, ovoid, often spinose, internal buds, consisting of two watch-glass-like shields, surrounded by a spongy, air-holding annulus; they are detached when the parent dies, generally in autumn, and grow in the ensuing spring; they have no blastodermic nor ciliated stage, but many have, according to *van Beneden*, a structure like a Purkinjean vesicle. In the

growth of the embryo in Rhabdopleura there are two fleshy side lobes attached along the dorsal edge, which do not increase as growth progresses, and are supposed by *Allman* to be the homologues of the mantle lobes of lamellibranchiate Molluscs. Rounded *germ capsules* are found inside polypide cells (zooecia), of which the original inhabitant has died. These are formed from protoplasmic masses below the fundus of the stomach, and originate new inhabitants for the deserted house. A second rarer way for new inmates to arise is by budding from the endocyst.

About 600 species exist, divided into two orders:—

1. Gymnolæmata (*Allman*)—with no epistome, a funnel-shaped mouth, and the 9–16 tentacles on a circular lophophore; they never develop statoblasts. This includes six sub-orders:—

Sub-order 1. Cyclostomata—calcareous, porous, each persona retractile into its cell; mouth terminal, wide; avicularia and vibracula none; cell-mouth with no crown of bristles; they are mostly fossil (Mesozoic); some have a jointed, colonial axis (Crisiadæ); others are unjointed, and with opercula to the cells (Myriozoidæ); the cells may have thin mouths, separate, protruding (Tubulata), or united in projecting bundles (Fasciculata).

Sub-order 2. Ctenostomata—retractile, with terminal, wide mouth, and no avicularia nor vibracula; the oval or cylindrical cells not pillared, but though separate, arising from a common stalk; cell mouth with a setose margin for its closure. The colony may be horny and crust-like, freshwater, each cell joined to 4–6 neighbour cells (Hislopiadæ, a passage form), or they may be marine, spongy, massive, or crust-like; the imbedded cells with contractile mouths (Alcyonidiadæ), or plant-like branched marine forms, upright or creeping, with projecting cells. A gizzard is always present in Vesiculariadæ.

Sub-order 3. Chilotomata—lophophore and sheath protrusible; cell mouth narrower than the cell, placed at the front near the terminal pole; mouth often with a horny operculum, or a sphincter; avicularia and vibracula often present, rarely very large and numerous, used as creeping organs (Selenariadæ); the colony in the other families is

firmly rooted, jointed (Catenicellidæ, Salicornaridæ, &c.), or unjointed, flexible, never attached for its whole length (Scrupariadæ, Flustridæ, Gemellaridæ, &c.), or incrusting, adherent directly to foreign bodies (Escharidæ, Hippothoidæ, Porellidæ, &c.)

Sub-order 4. Paludicellida—freshwater, horny; tentacle sheath not fully protrusible; cells spindle-like; mouth tubular; common stem none, includes one genus, Paludicella.

Sub-order 5. Urnatellida—one freshwater soft form, whose personæ are incompletely retractile into the semicircular cell; stalk jointed, slightly branched.

Sub-order 6. Loxosomida—a marine polypoid passage form with a pillar and foot; ten tentacles; no anus, and lateral gemmation.

Order 2. Phylactolæmata (*Allman*)—lophophore horse-shoe-shaped, with many tentacles, and an epistome; cells equal, without polymorphism; never calcareous; reproducing often by statoblasts (in the third sub-order only). This includes three sub-orders:—

Sub-order 1. Rhabdopleurida—marine, abyssal, with branched, adherent, membranous stock imbedding a chitinous rod, to which the polypides are attached by processes or funiculi. The bilateral lophophore has a large shield-like organ on its hæmal side, made of the two coalescent lateral embryonic lobes.

Sub-order 2. Pedicellineæ—one marine genus; cells soft, hemispherical, stalked, springing irregularly from a common stolon; tentacles solid, partly retractile, united at base into a calyx.

Sub-order 3. Lophopoda—freshwater, horny; the arms of the lophophore free or obsolete; cells cylindrical, dichotomously branched: tentacles fully retractile; colony with no special stem. These may have an adherent stock and statoblasts unarmed with hooks* (Plumatellidæ), or a discoidal colony and two circlets of hooks on the statoblasts (Cristatellidæ).

* Except in Pectinatella.

CHAPTER XXXIII.

CLASS 13.—TUNICATA.

SINGLE or aggregate, fixed or free, hermaphrodite,* marine Molluscoids; rarely symmetrical;† developed with metamorphosis; varying from the size of a pin's head to that of an apple, or larger in colonial forms; and sometimes divisible into three parts (named thorax, abdomen, and post-abdomen). The epidermis is often incrusted with sand, &c., or uneven, and sometimes consists of two layers, a superficial, non-cellular in Doliolum and Appendicularia, becoming cellular in others by immigration of cells, and a deeper epithelial containing larger cells compound to those of the chorda dorsalis of vertebrates, and crystals of calcium carbonate, and often stellate (Botryllus, &c.) or globular (Didemnium) spicules also of lime, rarely siliceous (Salpæ). Similar calcareous bodies in the flat Chelyosoma form two circlets of eight plates of horny consistence, four around the branchial, three around the atrial opening, and one intermediate. In Appendicularia the cuticle forms a remarkable case (the Haus, of *Mertens*), said to exist only in males.‡

The cutis is never separate from the cuticle, and forms with it the so-called outer wall of the mantle; it consists of connective tissue and pigment corpuscles (often stellate), and crystals, in a copious intercellular matrix, which consists of Tunicine, $C_{12}H_{10}O_{10}$, only differing from Cellulose by being

* Doliolum is diœcious.

† Pelonaia is bilaterally symmetrical.

‡ If Schizascus be a true tunicate, it is remarkable as having a bivalve shell (*Lacaze Duthiers*).

less easily saccharized. The consistence of the integument varies from that of soft mucous tissue to a leathery or gristly hardness; an inner polygonal cell layer lies underneath it. Fibre-like forms often traverse the cutis, as in Cynthia and Botryllus, and fat globules are common; rarely the entire surface layer is homogeneous (Appendicularia), or has a few scattered nuclei (Doliolum). The cutaneous vessels are often numerous, and end in dilated cæca. In colonial forms the integument is common to the stock, and takes its share in the protrusion of stolons for the growth of the colony, and by the vessels in it the vascular systems of the personæ may communicate. In Rhodosoma the dermis is in two symmetrical lateral folds.

The deeper muscular and connective layers are homologous to the sub-cutaneous laminæ of other vermes, and may be inseparable from the dermis (Monochitonida), or separate, except at the orifices, or where special bands unite them (Dichitonida). This condition has been used as a basis of classification by *Fleming*, but it is inconstant in allied species. There are two or three layers of muscle, an outer longitudinal, an inner circular, and sometimes a second longitudinal layer internally, usually in separate, not branched, bands; sometimes each fibre consists of cortical and medullary layers, and shows widely separated transverse stripes. Sometimes the circular are the stronger (Cynthia microcosmus), and in the swimming forms the sundered muscle bands are strong. Each orifice is usually guarded by a sphincter, and in the shielded Chelyosoma this is a six-sided figure with attachments to the under sides of the superficial plates. Six fan-like radiating muscles also exist in this form.

The body has two orifices, an anterior, oral or branchial, more or less wide, sometimes with a crenated border, or two lips, or four marginal grooves; some-

times with short tentacles; it leads into a branchial chamber often with plaited walls, whose lining membrane is vascular (papillose in Chelyosoma), and shows a deep, ventral, longitudinal, ciliated groove, bordered by two mucous folds or lips. At the floor of this ventral groove is an elongated, rigid, rod-like, whitish organ, the endostyle, hollow, ciliated at its base, with an outer sheathing layer of cylinder cells, within which is a clear membranous layer, and two rigid yellowish laminæ. Between the cutis and the muscular layers are dorsal and ventral longitudinal sinuses containing the blood, sending branches to the branchial membrane. This branchial chamber varies from a very small size to nearly the whole length of the body (Pelonaia); it is homologous with the breathing chamber of Balanoglossus; it often exhibits two ciliated bands extending from the front end of the groove for the endostyle to beneath the ganglion. The wall of the sac appears to consist of longitudinal and transverse bands, crossing at right angles, leaving quadrangular meshes; these bands contain branches from the dorsal and ventral sinuses.

At the fundus of the branchial sac the œsophagus opens, usually with radiating plicæ, and no lip-like folds; it passes ab-orally, often backwards, then dilates into a stomach, which may be fusiform, cylindrical, four-angled (Perophora), or with many internally projecting laminæ (Diazona), or divided longitudinally by seven or eight furrows stretching from the cardiac to the pyloric end. It may be simply striated, and the pylorus may be narrowed by a valve or by fleshy papillæ. The outer wall of the stomach is striated in Dendrodoa, and the cavity has a cellu-

lose lining in Cynthia. On the wall of the stomach is often a layer of yellow or green cells, some of which project inwards (Appendicularia). A somewhat similar coating of gland cells exists in Sidnyum; these may represent a liver. One or two gastric cæca in Salpa are also supposed to be hepatic. The short cæcal tubes of Chelyosoma, the long follicles of Cynthia, the separate lobular bodies of Phallusia intestinalis or Boltenia, are more specialized forms of hepatic organ. Amaurocium has a streak of glandular cæca on the stomach wall. The stomach is usually directed towards the hæmal surface, and ends in the intestine, which passes neurad; thus the digestive canal has first a hæmal and secondly a neural flexure, the latter being the most conspicuous and constant, while the former is due to a secondary spiral folding. No part of the intestine is protrusible. The tube has usually a thin muscular wall (absent in Salpæ), and is often suspended by thread-like mesenteries. It may be spirally folded throughout (Sidnyum), or only at its terminal part (Aplidium, Polyclinium). In Clavellina it is divisible into three regions, a clear, thin-walled part, a thicker glandular tract, and a thin rectal portion. Glandular cæca may open into the intestine, or it may have a coating of hepatic cells. In Boltenia reniformis, small sub-conical masses of nucleated connective tissue and protoplasm are attached to the upper surface of the rectum. The intestine contains usually diatom frustules, often Radiolarians, &c The hinder part of the canal may be surrounded by a narrow meshed plexus of vessels with whitish contents, forming a peculiar vascular appendage. The anus is on the surface beneath the tail in Appendicu-

laria, but in others it is at the bottom of an atrial or cloacal chamber beside the branchial cavity, whose opening may be simple or surrounded by a 10-11-cleft rosette. In the simple forms the cloaca is an irregular sac lined by a thin membrane. The neural side of the branchial sac projects into this chamber, and the partition is pierced by many openings with ciliated borders, whereby the water from the branchial enters the atrial chamber. The atrial opening in fixed forms is usually anterior and dorsal, close to the mouth. In free swimming forms it is usually directed backwards. In Polyclinidæ a tongue-like process can close this opening, and in others its lips may be crenated. In colonial forms each cluster of personæ may be grouped radially around a common cloaca, into which their intestines open.

The nervous system consists of a supra-pharyngeal ganglion placed usually between the oral and cloacal openings. A pair of nerves loop around the mouth, and may form a circumpharyngeal ring, but without an inferior ganglion. The nerve threads are primitive nerve fibrils, and those distributed to the muscles appear continuous with the fibres thereof; branches pass to the sphincters, to the muscular lamina, and to the viscera. In Appendicularia a nerve extends into the tail, in which it shows several successive enlargements.

(This tail in Appendicularia acts as a swimming organ, is longer than the body, and consists of a layer of dermis with or without epithelium, a layer of circular, and one of longitudinal fibres with the nerve cord, and a series of large nucleated cells in a homogeneous sheath, forming the tail axis.)

As sense organs may be reckoned the 6–30 oral, simple, rarely pinnate (Cynthia ampulla) tentacles when they exist, a ciliated, flask-like fossa in the middle-line of the back of Salpæ, in front of the dorsal end of the gill framework, may be a sensory organ like the groove in Nemerteans.

Red or yellow ocelli may exist around the mouth, or around both mouth and atrial opening (eight round the former and six round the latter in Phallusia). Pyrosoma has one red ocellus behind the ganglion. In Salpæ the horseshoe-shaped pigment speck may have many crystal cones and a nerve filament. A small auditory (?) vesicle lies on the ganglion in Chondrostachys. A similar clear round sac with a single otolith lies directly on the ganglion in Appendicularia. Another exists between the third and fourth muscular girdles, but not in the ganglion, in Doliolum. A sac is placed on the nerve centre in Salpa, with black pigment spots and four semicircular otoliths. In Chelyosoma an otocyst, with striated walls full of whitish material, lies close to the ganglion, and a second, pear-shaped, with a blackish body within, is in front of the ganglion. A sac, communicating with the respiratory canal by a duct, and lying on the ganglion, but without an otolith, has been also supposed to be sensory.

The heart is a simple fusiform or cylindrical tube, rarely ovoid or lobular (Cystingia), contained usually within a fine walled space (pericardium), and lying posteriorly and ventrally. It sends the dorsal and hæmal vessels into the branchial wall, except in Doliolum and Appendicularia; but there are no capillaries elsewhere, the blood circulating in lacunæ. In action the heart exhibits a curious unique alternation, discovered by *Van Hasselt*, first contracting in one direction, then stopping for a short time, then contracts in the opposite direction; it acts from 48–75 times a

minute, and has been noticed making 45–180 contractions in one way, then pausing for a time equalling the duration of two beats, and then making 170 contractions the other way. The blood is colourless, with ovoid or irregular corpuscles, rarely red. The heart is absent in Pelonaia. In Salpa it sends a branch to the closely united mass of viscera ("nucleus"), and a hæmal canal to the branchial chamber.

There are no external generative organs. Self-impregnation occurs, except in those cases of protandry where the spermatozoa are earlier developed than the ova, or in the diœcious forms. The testes are three or four milk-white pouches, usually around the ovary, and opening on a mammillary eminence into the cloaca. They are rarely symmetrical (Pelonaia). The spermatozoa have discoidal bodies and flagella. The ovary is usually a sac, opening into the cloaca; single (Phallusia), double (Boltenia, Pelonaia), racemose (Cystingia) opposite to it. *Carus* describes a second gland secreting the gelatinous covering of the ova.

The eggs are rarely developed directly, usually with the intervention of a larval stage, and sometimes one or two metagenetic forms intervene between each act of sexual reproduction (Doliolum).

In Ascidia and Phallusia the segmented yelk assumes its mulberry form, hollows within, and appears as a spherical, cellular body (blastula); a groove indents one side of this; the lips of the groove rise and close it in, except at one spot, and thus the body becomes bicavitary, the dorsal groove contracts, and the nerve ganglion develops either within it, or in its close vicinity. On a plane between the dorsal neural cavity

thus formed, and the ventral space, a double row of large cells appears, which extends into the tail, and forms an axis for that organ. These cells resemble those of the chorda dorsalis of Vertebrates, and have a similar relation to the neural and visceral cavities of the primarily bicavitary body to that possessed by the dorsal chord. Upon these phenomena, observed by *Kowalewsky*, *Kupffer*, and others, is rested the theory of relationship of Tunicates and Vertebrates, which is strengthened by the setting apart here of a portion of the digestive canal for respiratory purposes. A different, but much less satisfactory, interpretation of these appearances is given by *Dönitz* and *Mecznikow*. The embryo is usually tadpole-like, rarely without a tail (Molgula tubulosa).

In Appendicularia the branchial openings are formed by a double invagination, one outside of the skin and one inside of the pharynx. In all the endostyle is developed from the original epithelium of the branchial openings.

In Salpæ a curious life cycle exists. An egg develops within a brood-sac of a parent Salpa, and differentiates into two parts: one, the placenta, which is always on the hæmal side; and the other, the embryo itself. In this fœtal stage, digestive, nervous, and circulatory organs are developed, and at the hinder end of the fœtus a curious cluster of fat-holding cells, the elœoblast, forms, which soon afterwards disappears. This solitary form soon becomes free-swimming, and from the ab-oral side of the heart it develops a thread-like organ, which elongates, thickens, and segments into a chain of variously aggregated Salpæ, which have communicating circulatory organs. Each

of these aggregated Salpæ again develops sexual organs, and from their eggs a second brood of solitary Salpæ spring.

In the compound forms, like Botryllus, a simple egg develops an embryo with one tail and a many-lobed body with a central opening, the cloaca, around which each lobe becomes a persona.

The egg in Pyrosoma develops an incompletely organised embryo or cyathozooid, which by budding gives rise to four zooids united together by a vascular cord. The tubular heart of the cyathozooid has a peripheral sinus between its two tunics, and is the centre of a social vascular apparatus, whereby the embryo is nourished.

Three types of aggregation are met with among the Tunicates—1st, solitary forms; 2nd, social zooids connected by a common vascular system; and 3rdly, compound, united by a fusion of the dermis, but with no internal union. These forms have a single, sometimes branched, cloaca for each colony.

About 300 species are known, some of which (Pyrosomæ and Salpæ) are brilliantly phosphorescent. The light in Pyrosoma emanate from two lateral cell masses, formerly considered to be ovaries (*Panceri*).

They are divided into two orders:—

1. Thaliaceæ (*Troschel*)—free swimming, simple, or united, prismatic or cylindrical, with a clear cutis; the openings at either end; gills as a band in the branchial chamber; development metagenetic. Family 1. Appendicularidæ—tailed, like the larvæ of other forms; cloacal; respiratory organs with one opening and two tubular spaces; ovaries and testes post-intestinal; the cutis forms a house or theca; heart does not reverse its actions. 2. Salpidæ—mouth and cloaca opening at opposite poles; heart reversing its actions alternately; circular muscular bands usually well marked; viscera in a

round opaque mass at one end of the body (nucleus) in Salpa, but not in Salpella. Anchinia has no muscular bands for locomotion. 3. Doliolidæ—barrel-shaped, with equal, regular, hoop-like, circular muscle-bands; gill cavity flat. 4. Pyrosomatidæ—stock a cylindrical tube open at one end, made up of many individuals united; each persona opens outwards and inwards by its polar mouth and cloacal openings respectively. The gill sac is like that of an Ascidian proper. Each egg develops four individuals, which rapidly multiply by buds from the endostyle. 5. Kowalewskiidæ—heart, endostyle, and intestine absent; pharynx ciliated with four rows of teeth, otherwise as in Appendicularia.

Order 2. Chthonascidiæ (*Brown*)—fixed, rarely imbedded in sand or mud; mouth and cloacal opening at one end more or less tubular, with the ganglion between them; branchial sac regular, with many rows of gill slits.

1. Pelonaiadæ—imbedded in mud; individuals united, with no heart and symmetrical sex organs. 2. Ascidiadæ—fixed to stones, having a heart, undergoing metamorphosis in development; sex organs unsymmetrical. Chelyosoma is flat, and has the peculiar many-angled plates above described. Rhodosoma has a two-winged cutis. Boltenia is long stalked, with four rayed openings and compound tentacles. Cystingia is similar, with an irregular anus. Dendrodoa has a longitudinally folded gill sac and a tentacle crown, and one (left) ovary, while Cynthia has two and Pandocia has one ovary (the right). Molgula has no longitudinal folds in the branchial membrane, an eight-lobed mouth and a six-lobed cloacal opening. Phallusia has a six-lobed mouth and a four-lobed atrial outlet. 3. Clavellinidæ—family stock branched, with stalked personæ, and often with common circulation. There may be creeping stolons (Clavellina), or a single stolon with a few individuals (Perophora), or in compound, greenish, large masses (Syntethys). In Chondrostachys the individuals are grape-like on an upright stem. 4. Botryllinidæ—compound, usually forming an expanded, mucous, or spongy, often lobed mass, united by their common cutis, but without common circulation. They are divided into three sub-families:—(a). Botryllinæ—having the personæ united around

the common cloaca, the abdomen not sharply marked off; they may be regularly arranged (Botryllus) in stars or discs, or irregularly (Botrylloides). (B.) Didemninæ—having the body divided into thorax and abdomen, and each embryo producing two individuals. In Leptoclinum there are few systems and a six-lobed mouth. Encœlium has many systems and an obsoletely rayed mouth. Didemnium has many systems and a pedunculate abdomen. Distomus has one or more circles of personæ, and each has a six-rayed mouth and anus. Diazona has regular concentric circles of personæ forming a rosette-like disc. (C.) Polyclininæ—body with not only a thorax and abdomen, but a post-abdomen, containing the heart. Polyclinum has a pedunculated post-abdomen; the mouth is six-rayed; the anal opening prolonged horizontally and irregularly cut. Aplidium has the anal opening indistinct, and no central cavity. Sidnyum has an eight-toothed branchial opening, and a simple, tubular, folded, anal opening. Synoicum has a six-rayed mouth, an irregularly six-rayed anus, and a sessile post-abdomen. Amourocium has indistinct abdominal divisions; mouth six-rayed. In Parascidium the mouth is eight-rayed, with two eye-specks. Sigillina is seal-like, the narrowing circlets rising one over another.

CHAPTER XXXIV.

SUB-KINGDOM 6.—MOLLUSCA (*Cuvier*).

MOSTLY aquatic, soft-bodied personæ, composed of one, two, or three obscurely marked metameres, with a concealed bilateral symmetry. Their structure can be easily understood by regarding them as Vermes*

* We know as yet of no absolute passage forms or direct synthetic types.

with no articulated appendages, modified by unequal lateral development, and by a fusion of metameres.

The integument and muscular layers unite to form a contractile envelope,* consisting of—1st, an epidermis, ciliated in the embryo,† becoming superficially tesselated in the adult, or forming a laminated cuticle, pierced by non-glandular pore canals, as in some Cephalopods; 2nd, a dermis of connective tissue, sometimes cartilaginous in parts (Carinaria, Loligopsis), containing glands,‡ pigment cells,§ often granules, spicules, or networks of carbonate of lime;‖ sometimes with follicles giving origin to bristles like those of Chætopods,¶ or rarely with clusters of cnidæ like those of Turbellaria;** 3rd, a muscular layer, never separable from the last, usually consisting of interrupted bundles of transverse fibre cells externally, and of a more continuous inner layer of longitudinal fibres.

The head of the larva is furnished with an expansion of the integument for locomotion, the Velum,

* When there is much connective tissue, as in the clear dermis of Heteropods, the capacity of form-change is small. The development of a shell also limits its contractility.

† In the adult, ciliation is confined to the gills, except in a few forms, as Phyllirhoë.

‡ These are—1st, unicellular glands like those in worms; to these the goblet cells, scattered on the surface of some molluscs, seem to be related; 2nd, mucous glands, with ducts scattered over the surface as cæcal follicles; 3rd, colour glands secreting a deep purple fluid, as in Murex, Aplysia, and Purpura. These are usually limited to areas on the surface.

§ Chromatophores, or connective corpuscles filled with pigment, having radiating, muscular fibre cells (?) attached to their periphery, whose contraction causes the cells to assume a stellate appearance, found in Cephalopoda and Pteropoda.

‖ As in Doris, &c.

¶ As on the mantle edge of Brachiopods and Chitons.

** As in the dorsal papillæ of Œolidæ.

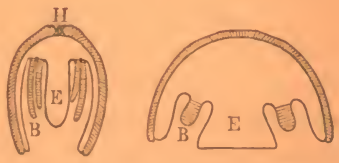
margined by a crown of large, simple, or clustered cilia, sometimes bilobed, with an anterior and posterior median notch, or divided into four or more tentacle-like lobes, which may have ciliary girdles. This is a form of the primary ciliary crown of the larvæ of Vermes, like the lophophore of Polyzoa. A fold of integument at each side of the body is called the *mantle*, and may be single and continuous, or of two lateral, united, or separate lobes; it may be present in the embryo, and lost as age advances, or may be absent. The mantle lobes are probably homologous with the basal papillæ of the notopodia, and between them on the ventral surface the dermal and muscular wall is developed into a thick process or *foot*, the chief organ of progression, which may have a flat sole or a sharp edge, and may be rudimental in sessile forms (oysters, &c.) As this is the ventral surface of two or three united metameres, it may be divided into two or three parts, named, respectively, pro-, meso-, and meta-podium; sometimes it is longitudinally divided into a middle and two lateral parts. The relation between the foot and the under surface of the ordinary body wall of a worm is shown by the fact that the viscera are often prolonged into, and lie above it; its upper surface may develop an appendix or epipodium.

When the mantle is present it usually secretes a shell,* more or less completely enclosing the body; in its simplest form this is a single lamina on the mantle surface (*univalve*), or when the mantle is bilobed it consists of two plates united dorsally by a hinge, and is called a *bivalve*. The first form may be

* Composed of Conchiolin 0.04, Calcium Carbonate 0.94, Calcium Phosphate, Alumina, Iron, and Silica, 0.02 = 1.00.

laterally symmetrical, but from unilateral growth often assumes a spiral form. Shells increase in extent by additions secreted by the thick and glandular margin of the mantle, in the form of long prismatic cells, or minute, conical shell-columns. The surface of the mantle secretes the nacreous or mother of pearl layer, which increases the thickness of the shell, and consists of thin overlying plates, whose wavy, out-cropping edges, viewed by reflected light, appear iridescent. The outside of the shell is coated with a fine *periostracum*, a horny cuticle often covered with hair-like or laminated processes. The shell may develop internal processes, as in Brachiopoda, but it is always an epidermal structure. An internal skeleton sometimes exists as a series of symmetrical, simple, cellular cartilages around the pharynx or œsophagus, but not homologous with any specific part of the vertebrate endo-skeleton. The muscular system is, as a rule, feebly developed, though special parts of it, modified by the forms of the shell and foot, may be very strongly marked. The nervous system consists of a pharyngeal ring, having a pair of epi- and a pair of hypo-pharyngeal ganglia united by commissures; of these, one or other may preponderate, or they may become fused or sub-divided, or their commissures may be short or long. The hypo-pharyngeals are often displaced downwards into the foot, and hence

Fig. 30.

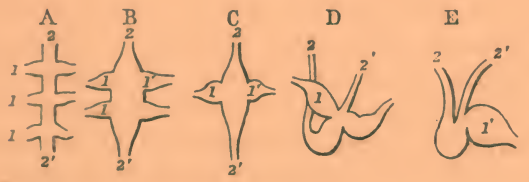


A, transverse section of Bivalve Mollusc; H, hinge; E, foot; B, double gill lamella: the shaded outer layer is the shell, the clear space internal to it is the mantle. B, section of Gasteropod; B, gills; E, foot.

are called pedal ganglia. Two long (sympathetic?) nerves, arising from the œsophageal ganglion, may unite posteriorly to form a parieto-splanchic or anal ganglion. Sense-organs may exist as tentacles, ciliated smell organs, eyes, otocyst, &c.

The digestive canal never communicates with the body cavity, and is more or less looped, so that the anus is often near the mouth, and always near the breathing cavity. The intestine is sometimes attached to one or more rudimental transverse partitions, traces of the metameric septa. There are often dental organs, sometimes a crop, always a liver. The circulation is lacunary; the blood clear (rarely coloured),

Fig. 31.



A, segment of the dorsal vessel of a Worm; 1, 1, 1, inferent vessels; 2, cephalic end; 2', abdominal end. B, heart of Nautilus; 1, 1', auricles; 2, cephalic aorta; 2', abdominal aorta. C, heart of Lamellaibranch or Loligo. D, heart of Octopus. E, heart of Gasteropod.

corpusculated, and propelled by a heart, which resembles a segment of the circulatory system of worms (Fig. 31), receiving blood from one or two pairs of dilated, transverse vessels distended into auricles, or rather into dilated, branchial sinuses (Fig. 31, 1, 1'), which receive blood from the gills, and empty it into a longitudinal dorsal vessel, modified into a ventricle, usually straight, rarely flexed on itself, and sending forward a cephalic (Fig. 31, 2), and backwards an

abdominal aorta (Fig. 31, 2′). A part of the body cavity surrounding the heart is called the pericardium. Some regions of the integument, either the mantle itself, or a single or double pair of folds within the mantle lobes, or an area of the skin of the back, become spongy and dilated as breathing organs, or gills. In land molluscs the cavity within the mantle lobes, or part of it, is set apart as an air-breathing space or pulmonary cavity; but the breathing organs are never combined with the pharynx, and are always ciliated.

One or two pair of excretory organs (modified segmental organs) commonly exist, opening both on the surface and into the body cavity; these may be simple tubes, or may have glandular walls. When largely developed, they receive blood from the viscera, and transmit it directly to the gills, forming a rudimental portal system. The outer openings of these organs may receive the ducts of the sexual organs, or may open in common with them, or may be separate. Other renal organs, special developments of the vascular system, exist in Cephalopoda and Brachiopoda.

Molluscs are usually hermaphrodite, with a single sex gland (often placed close to the liver), some of whose acini produce ova, others spermatozoa. The male and female products may be emptied by a common duct, or the oviduct and vas deferens may arise in common, and then separate, and finally reunite, or the primary common part may be short or absent. Various accessory organs are appended in some classes. Development is attended with some form of metamorphosis. The ova are holoblastic, except in Cephalopoda.

Mollusca are mostly marine; a few are pseudo-

parasites.* They can be arranged in two divisions :—

Division 1. Brachiopoda (*Dumeril*)† — marine molluscs, usually small,‡ included in a bivalve shell whose line of articulation is hæmal, transverse, and whose valves are ventral and dorsal, equilateral, but dissimilar,§ the ventral being usually the more convex, overhanging the dorsal at the hinge, and often having a longitudinal median furrow, while the dorsal has a median ridge. The valves are opened‖ and closed by muscles, and have no elastic ligament, and the beak of the ventral valve is often pierced by a hole¶ for the passage of a pedicle by which the shell is attached to foreign bodies, or the surface of the ventral valve may be itself adherent (Crania, Thecidium). All the adult forms of living species are fixed.**

The shell is generally dull-coloured,†† slow-growing, laminated, and marked on the surface with concentric lines of growth,‡‡ often with radial ridges, alternate on the opposite valves, sometimes (in fossil forms) with hollow spines. The shell has no nacreous layer, but consists of elongated, parallel,

* Vulsella, Coralliophila, Magilus, Gastrochaena, are found in corals, Stylifer in Starfishes, Eulima in Holothurians, Entoconcha mirabilis in Synapta, &c.

† Palliobranchiata (*Blainville*), Brachionopoda (*Brown*), Spirobranchiata (*Schmarda*).

‡ From 0.01″ to 3″ in length ; often as broad as long.

§ The valves are scarcely distinguishable in Lingula.

‖ But in the hinged forms can only open for a very small distance, in Waldheimia from $\frac{1}{8}$″ to $\frac{1}{10}$″, unless violence be used.

¶ The opening may be in the back, between it and the hinge, or between the two valves (Lingula).

** When set free the dorsal valve, being heavier, is downward.

†† Usually grey or brown. Waldheimia picta is spotted; Rhynchonella is very dark; Lingula green and brown; Crania white.

‡‡ Sometimes lamellose, as Orbicula, Crania.

conical prisms placed at angles of 10° or 12°, with the surface of the shell. Through the shell are vertical perforations, finer internally than externally, only absent in Spiriferidæ and Rhynchonellidæ, occupied by processes of the outer layer of the mouth, compared by *Huxley* to those whereby the tunic adheres to the test in Tunicates. Sometimes the shell is horny and chitinoid (Discina); in Lingula it consists chiefly of calcium phosphate (85. per cent.), with carbonate (12.) and magnesium carbonate (2.). Waldheimia has more calcium carbonate. The perforations may be branched towards the surface (Crania), or fine and parallel, like dentine tubes (Lingula, Discina). The shell prisms are usually equal and with rounded bases, but may be unequal and irregular (Crania). The ventral valve presents, near its articulation, and beneath its beak, a convex or flat surface (*hinge area*), in the centre of which is a triangular depression (*deltidium*), which may be single (*d. discretum*), or with a median division (*d. sectans*), or partly surrounding the perforation (*d. amplectens*). The opening at the summit of the deltidium is the deltidial opening. The shell is often auricled, beside the hinge area. The two valves may be united only by soft parts (neither by a hinge nor an elastic ligament), or by a long straight line of contact, without teeth (Productidæ, Chonetidæ), or by a perfect hinge, consisting of two teeth on the ventral valve fitting into two sockets on the dorsal. The outside of the shell is covered by a fine periostracum. The peduncle of attachment varies in length from a few lines to several inches (Lingula); it is thick, brownish, semi-cartilaginous, flexible, scarcely elastic, with a single or double (Lingula) horny sheath, with sometimes an inner cylinder of longitudinal muscles within it (inner pillar muscle, as in Lingula). A musculus peduncularis extends from the ventral valve to the base of the pedicle in Waldheimia. A pair of these exist in Rhynchonella.

Within the shell in Terebratulidæ, Spiriferidæ, and Rhynchonellidæ are internal processes of calcareous matter, forming a loop for the support of the *arms* characteristic of the group. These consist of the same material as the shell, but are imperforate in Terebratulidæ. They are attached to

the dorsal valve, and may arise from each side of a flat inner hinge plate (Waldheimia), or from an internal longitudinal median ridge running along the dorsal valve of the shell (septum dorsale*), as in Bouchardia and Kraussia, or from both (Terebratella, Morrisia), or from the inside of the valve itself. The base of the loop on each side is called the *crus*, and often has a *crural process* or spur passing inwards, which may join its fellow of the opposite side, forming a *crural bridge*. The loop itself may be short, down-directed, or may bend again upwards and backwards, and its two limbs may remain separate (and become spirally coiled as in the extinct Spirifers), or may unite, forming a terminal bridge.

The mantle is bilobed, full of lacunary blood spaces, the chief agent in respiration, as no separate gills exist. The mantle surface often contains calcareous spicules, sometimes branched, or united into a crust. Its free border is beset with separate or clustered, long, transparent, ringed bristles† arising in special glandular follicles, movable by muscular fibres attached to them at their bases. The mantle consists of an outer, netted, connective layer, an inner, homogeneous layer, and a central lacunary area, bounded by a reduplication of the two laminæ. Muscular fibres, anterior and posterior parietal muscles, exist in it, especially in Lingula, passing from one mantle-lobe to the other.

The arms are two, long, hollow, symmetrical processes, when at rest folded with 1–20 spiral windings, or S-formed (Morrisia), and placed one at each side of the mouth, attached to the loop of shell when it exists. They consist of semi-cartilaginous connective

* Double in Pentamerus.

† Branching in Discina.

tissue, and are united at their base by a band of the same material. A groove runs along the upper surface of each, bordered by a double row of many parallel sub-rigid bristles or filaments, each of which is clothed with cilia; three muscular bands lie under the groove and attached to these bristles, which can move them (*a*) outwards, widening the groove (*b*), inwards, narrowing it, or (*c*) downwards. These bristles are contractile* and hollow, with calcareous supports in Spirifer rostrata and Terebratula pectunculoides. The arms themselves are traversed by large canals, and are chiefly moved by the distension of these with fluid, which enters from the body cavity, and is retained by the action of circular basal fibres. Each arm contains—1st, a chief canal beginning cæcally at its base; 2nd, a small afferent canal whereby the bristles may be distended; 3rd, an efferent canal; 4th, a prolongation of the body cavity forming an arm pouch; and 5th, a canal at the base for the reception of the calcareous loop support. Besides these are numerous lacunæ for blood.

Fig. 32.

Muscle of shell o Waldheimia seen inf section.

The muscles which move the valves of the shell are:—1st. Two pair of *occlusores, anterior and posterior,* passing from valve to valve, tendinous medially in Rhynchonella and Terebratula. 2nd. Two pair of *divaricatores* from the ventral valve to the hinge process of the dorsal, one chief and one accessory pair; these are the cardinal muscles of some authors. 3rd. *Adjustor ventralis,* from the ventral valve to the peduncle. In Lingula there are three adjustors (*a. externus, centralis,* and *posticus*); of these two (external and

* A respiratory function is assigned to these.

central) are the homologues of the ventral adjustor of Waldheimia.

The mouth is a transverse slit between the arms; beneath it is a prominence or lower lip, the homologue of the foot of Otocardians. The short, undifferentiated pharynx and œsophagus pass in front of the crural processes of the shell between the occlusores, and end in a stomach, which may be oval, tubular, fusiform (Crania), or lenticular (Lingula); from it, towards the ventral valve, passes the intestine, which is either short, with one neural flexure and with a cæcal end (Terebratulidæ, Rhynchonellidæ), or long, coiled, traversing the liver, and ending in a papillary anus (Lingula, Discina, Crania). The first form is a secondary degradation, since in Thecidium, an impervious cord from the cæcal intestine passes to where the anus would be. The intestine is fixed by a longitudinal mesentery of two parts, dorsal and ventral, extending from behind the œsophagus to the end of the attachment of the occlusor muscle. Two transverse partitions, the remains of the inter-metameric septa, also suspend the intestine. The first, gastro-parietal, consists of a middle (absent in Lingula) and two lateral portions; the second, or ilio-parietal, is farther back. The liver is a multilobar mass made of many cæcal pouches, with many ducts in Crania, four in Lingula, two on each side opening into the stomach; in Lingula two lobes are in front, and two behind the gastro-parietal band.

The circulation is lacunary, the vessels (excepting a few primary ones) having no proper walls. The heart is a saccular organ, lying on the stomach behind the middle gastro-parietal bands; it has two

walls, an outer homogeneous, an inner muscular.* It receives an anterior stem from over the œsophagus, and sends off lateral branches; the vein collects the blood of the lacunæ and of the mesenteric spaces. The two lateral vessels are united for a short distance; each divides into two branches, anterior and posterior; the former going to the dorsal lobe of the mantle, and giving off medial and lateral branches; the dorsal branch supplies the reproductive glands, the other traverses the ilioparietal septum, over the excretory organ, and supplies the ventral lobe of the mantle. In the wall of the mantle are two accessory hearts or pyriform sacs receiving and transmitting blood; these are probably homologous to the venous accessory organs in Cuttlefishes. There is no pericardial segment of the body cavity, unless the space included in the ilioparietal septum be considered as such.

One or two pair of excretory organs exist, which are modified segmental organs. In Rhynchonella one pair is dorsal and one ventral. The dorsals are absent in Lingula and Terebratula; in the former the ventral organs lie between the two layers of the ilioparietal septum. They open by a tubular part externally near the bases of the arms, and by a radially folded funnel, which has been mistaken for a heart, into the body cavity. In Terebratula the tubular part is short, and the mouth separated by the occlusores; the tubular part is lined by glandular epithelium. This tube is the usual channel for the extrusion of the sexual products.

The nervous system consists of a large hypo-

* Lingula has no heart (*Semper*), and the circulation is carried on by cilia in the large vessels.

pharyngeal ganglion, sending two lateral, visceral branches, which form two small, lateral œsophageal ganglia, and end in two labial ganglia. From the large ganglia come off laterally nerves to the upper mantle lobe and to the arms. Two cords pass beside the œsophagus, forming a pillar-like pair of ganglifform swellings, sending branches to the ventral mantle lobes. There is no œsophageal ganglion in Lingula, but two lateral ganglia, sending many radial nerves in the mantle. Two similar ganglia exist in Discina.

Most Brachiopods are hermaphrodite; a few (Thecidium, &c.) are diœcious. The sexual gland is a four-(rarely two-) lobed yellow mass, either in the body cavity, and partly round the intestine and muscles (Ecardines), or in the space between the mantle lobes. (Testicardines). How impregnation occurs is unknown; but as they are always in clusters, there would not be much difficulty. The sexes in Thecidium differ in the shape of their shell, and this genus has also a brood-pouch wherein the eggs are retained by fine filaments. The embryology of Brachiopods confirms strongly their relationship to Vermes. The ova appear first as caudate ciliated bodies, early developing a bilobed mantle, and a velum or ciliated head-lobe, on each side of which are four, hollow, ciliated processes. The free larva has two ear-vesicles on the nerve centres, disappearing in the adult. Eyes also exist as pigment spots, which also disappear. The intestine early develops, and the velum is modified into the arm basis. The fry of Discinæ have been found attached to the valves of their parents, and the fossil Stringocephalus has been found with many embryo shells within it. Some larvæ creep by means

of a pair of spines, one on each side of the ventral mantle lobe.

Of the 2000 species known, only 80 are living; the others are mostly palæozoic. They are more abundant in the Southern than in the Northern Hemisphere, and live at depths of 10–200 fathoms. The horny shelled forms are littoral and sub-littoral. They are most abundantly found on a stony bottom, and feed on Diatoms, Sponges, &c.) This division includes two orders:—

1. Ecardines (*van der Hoeven*)—intestine long, with a lateral anus; shell hingeless; no arm supports; a vasiform heart; mantle margin ununited; generative glands in the perivisceral cavity. Herein are the families:—1. Lingulidæ—horny, tubular shells, with a muscular peduncle, springing between the beaks of the two nearly equal shell valves, ex. Lingula, from the Pacific. 2. Discinidæ—chitinous shell, with an opening in the under valve (Discina, Pacific). 3. Craniidæ—calcareous shell adherent by the under valve (Crania, Atlantic).

Order 2. Testicardines (*Gegenbaur*)—digestive canal short, aproctous; mantle lobes united behind; shell calcareous, with a hinge line and prismatic structure. This includes the following families:—Rhynchonellidæ—arm loop calcareous, of two parallel crura; shell with no area; hinge line curved or straight; both valves convex and radially ribbed; rarely punctated; the beak in Rhynchonella is imperforate (Mediterranean and Pacific). 2. Terebratulidæ—arm support strong, looped, never spirally developed; shell biconvex, perforate at the beak, and punctated; of the included genera the shell is directly adherent to stones in Thecidium, attached by a peduncle in others; the loop is very short in Terebratula, longer and reflected in Waldheimia, attached to the septum dorsale in the long, narrow Bouchardia; the loop for the sigmoid arms in the minute Morrisia is not reflected. Kraussia has small oral arms and a transversely ovate shell, and sometimes a branched apophysis. Megerlia has the loop trebly attached to the hinge plate, and by two slips to the septum.

Of extinct families Spiriferidæ (Palæozoic) has spirally coiled diverging arm supports and an impunctate shell.

Chonetidæ (Palæozoic) has a tooth-bearing hinge and tubular spines. Strophomenidæ (Palæozoic, Leptaena, also Liassic) is similar, but with no spines. Productidæ has no teeth in the hinge, only a straight line, and the dorsal valve often concave.

CHAPTER XXXV.

DIVISION 2.—OTOCARDIA (*Haeckel*).

MOLLUSCS having hearts consisting of one or two auricles and one ventricle. The integument is differentiated dorsally into a mantle, ventrally into a foot. The nervous system consists of a pharyngeal ring with, usually, epi- and hypo-pharyngeal ganglia, and one or more visceral ganglia united to the epi-pharyngeal by commissures. Three classes are included herein :—

1. Lamellibranchiata (*Blainville*)*—aquatic, mostly marine, fixed or free; with a large mantle usually covering the whole body, and consisting of two, more or less, symmetrical lateral lobes, continuous from before backwards, and overhanging the mouth, attached together medio-dorsally, and secreting on its outer surface a shell of two lateral valves. There is no specialized head-segment with centralized sense-organs. The shell is often equivalve (except at the hinge). The valves are rarely equilateral,† and are united medio-dorsally by a longitudinal, movable

* Acephala, *Cuvier*; Bivalvia, *Linnaeus*.

† As in Pectunculus.

hinge, outside which is an elastic ligament, which during life keeps the valves open.

This consists of an outer thickening of the periostracum, over a layer of "cartilage" consisting of an iridescent material soluble in caustic potass, which exhibits two sets of striæ, vertical and horizontal; this lies in a pit or chondrophore, often elongated and spoon-like (Mya, Mactra), sometimes multiple.* Each shell valve has on its upper edge, overhanging the hinge, a beak or umbo, which may be central (Pectunculus), but is usually nearer the anterior (mouth) side, which is thus shorter than the posterior, which bears the ligament.† The umbo may be straight (Mytilus), or bent forwards (Venus, &c.), rarely backwards (Lyriodon), or spirally coiled (Isocardia. Diceras, Chama). The right valve may be smaller than the left (Ostrea, Pandora, Lyonsia), or *vice versa* (Chamostrea and Corbula). The periostracum may be evanescent or permanent, often bristled or tufted; sometimes prolonged beyond the edge of the valves (Solemya, Cyrtodaria), or extending over the siphon (Mya, Glycimeris, &c.) The shell surface is marked with concentric lines of growth, beginning around the umbo, also with radial lines, ridges, scales, or spines, corresponding to irregularities in the mantle border. The valves may be capable of perfect closure, or may gape posteriorly for the emission of the siphons, rarely in front (Rocellaria, Gastrochaena) for the protrusion of the foot, or ventrally (Galeomma). At the hinge there are teeth in each valve fitting into corresponding hollows in the neighbouring valve. Those directly under the beak are *cardinal;* those in front or behind it are *lateral.*‡ The cardinals may

* Iridina, Crenatula.

† In Donax, Glycimeris, Solemya, &c., the umbo is nearer the hinder than the front edge of the shell.

‡ Sometimes the teeth are formulated e.g. $C\,\frac{r.\,2}{l.\,3}\;\; l\,\frac{r.a.1}{l.a.2}.\;\frac{r.p.1}{l.p.2}$ (meaning Cardinals, $\frac{\text{right valve 2}}{\text{left valve 3}}$, laterals $\frac{\text{anterior on the right valve 1}}{\text{anterior on the left valve 2}}$, $\frac{\text{posterior right 1}}{\text{posterior left 2}}$).

be rudimentary, or the laterals or all may be absent (Mytilus). The animal may lie permanently on one side, having its smaller valve uppermost, and this side may be constant for the species (Oyster, Pecten, &c.), or may vary (Chama). A few are found in the morphological position with the foot downwards, fixed (Humphreysia), or free (Lepton). Under the periostracum in the shell is a layer of prismatic elongated cells; polygonal in section; secreted by the mantle edge; deeper in the nacreous or mother of pearl layer; secreted by the mantle surface; constantly increasing in thickness during life. The prismatic layer is absent in Cyclas, &c., and the membranous wall of the shell is there pierced by many pore canals. The outer stratum of this layer in other shells is pierced by many branching tubes (the hyphæ of a fungus, *Kölliker*). Foreign bodies between the mantle and the shell become coated with this shell layer, and form pearls. A fine, white, structureless layer underlies the nacre, consisting of calcareous granules in an organic basement. The sizes of shells vary from 1″ to 2½′, and the weights from 3 grains to 300lbs. The colors are white, reddish brown, green or olive (the last in freshwater forms).

Irregularities of structure and arrangements are met with in the shells of the extinct sub-class Endocardines, and in the living Tubicola, where the animal inhabits a calcareous tube, to which the valves may be solidified (Aspergillum), or the right solidified and the left free (Clavagella). In these the hinge ligament is at first flexible, but becomes calcified. In Anatinidæ a calcareous nodule develops in the hinge cartilage.* Shells may have flat processes on each side of the umbo (*auricles*, as in Pecten, or, when large, *alae*, as in Perna Avicula). In Spondylus the teeth are locked, limiting the motion of the valves. In Pholas, beside the ordinary lateral valves, there are other accessory shell plates, two umbonal plates, a dors-umbonal, and a dorsal in place of the ligament. The shell structure in the teeth of many forms is radiate, appearing in sections like the mineral Wavellite. Shell con-

* In Venus, Cardium, &c., the cartilage is very small, in a cavity between the primary teeth.

sists of conchiolin 4 per cent.; calcium carbonate 94 per cent.; phosphoric acid, silica, iron oxide, &c., 2 per cent. The optical properties of the calcium carbonate agree with those of Arragonite.

The mantle lobes may be free from each other along the lower margin (*unifora*), as in Ostrea and Pecten, or they may be united at one spot, so as to leave a small hinder excretory and a very wide anterior slit (*bifora*). In others the anterior opening is subdivided by a second union, so that there is an anterior or foot opening, a middle or ingestory, and a posterior or exhalant orifice (*trifora*). The walls of the latter pair of orifices may unite and be elongated in the form of a double-barreled tube whose upper canal is exhalant or excretory, and the lower is inhalant (or both may be used indiscriminately, *Clark*). Sometimes the anterior or foot orifice is tubular, siphon-like (Kellia). The mantle consists of epithelium on both sides of a connective basement, having along its free border muscular fibres and glands, and containing blood-vessels, or lacunæ, and nerves—often tentacles, &c. In Teredo the mantle contains cells like the cellulose-holding elements of Phallusia. The line of attachment of the muscular fibres of the mantle to the shell is called the *pallial line*, and is roughly parallel to the lower edge of the shell, often interrupted (Ostrea, Saxicava, Panopæa, &c.) When a siphon exists, the hinder edge of the pallial line is indented by a deep *pallial sinus* whose fundus points forwards, and whose depth is proportional to the length of the siphon (sometimes as in Cyclas a siphon may exist with no pallial sinus). The wall of the siphon contains circular fibres around each tube, and longitudi-

nal retracting fibres over the wall of both tubes. The distal end of the siphon is often fringed by sensitive processes (siphonal tentacles, as in Mya).

The mouth is directed forwards, and bordered by two or more ciliated, sensitive, labial tentacles,* like the base of the arms in Brachiopoda. There is no odontophore, nor salivary gland (Teredo has two irregularly-lobed, oral glands with a common duct). The œsophagus is short (long in Teredo); the stomach globular or oval, and the intestine has one, neural, or 2–12 flexures† (most numerous in Cardium). On the right of the stomach there opens a cæcal pouch imbedded in the liver, or between it and the genital gland, containing a curved *crystal style*, or transparent rod, rounded at one end, which is often attached by a triangular process, flattened or pointed at its free end, and made of tesselated epithelium, sometimes lamellar, or with calcareous particles in it: this is irregularly periodic in development, being largest after the winter. Its cæcal pouch has a valvular opening, and rarely is rudimental, the style then lying in the intestinal tract; it is only present in Anomia among the Monomya, absent in Ostrea, &c., and is sometimes absent in Cyclas, Pisidium, and Galeomma. It may act as a gizzard. The intestine having traversed the liver, next pierces through the ventricle of the heart (except in Ostrea, Anomia, Teredo); then, passing over the main (posterior) adductor, ends in the cloaca.

* Small in Lucina, Corbis, &c.

† Unio has three concentric coils, of which the first is marked by a pair of longitudinal ridges on its mucous membrane; the second, which projects into the foot, by transverse folds, and the third by longitudinal ridges.

A solid diverticulum passes from the upper surface of the intestine behind the muscle in Pinna (the trachea of *Poli*). The cloacal may be quite separate from the branchial chamber. The liver is many-lobed, acinose, often mixed with the sex gland, and opening by two, three, four, or many ducts, into the stomach and upper end of the intestine.

The foot or ventral surface of the body is usually laterally compressed, sharp-edged, never trifid, nor provided with an epipodium; it may be straight (cormopoda) or bent on itself (pelecypoda), ploughshare, or club-like, or rudimental, in sessile forms (Ostrea, Anomia),* or may be provided with a gland secreting a silky chitinoid material (byssus), whereby the animal is anchored.

There are two pair of retractor muscles for the foot (one pair in Dreissensia), the anterior arising from the inner surface of the shell close to the umbo, the posterior being near the attachment of the hinder adductor. (An additional pair of retractors, behind the anterior adductor, exist in some Unionidæ.) There is one protractor of the foot arising behind the anterior adductor and passing in front of the foot. The muscles are smooth and longitudinally striped. The base of the foot receives the liver, digestive canal, and sex gland.† In boring forms it is cylindrical, and has siliceous particles in its dermis. The foot may be pierced by an opening (Unio), leading into a long canal which ends in lacunæ; from these the water flows when the foot is suddenly retracted. Galeomma has a double canal; Cyclas has many sieve-like openings; Mactra one large aperture.‡ The byssus gland is

* Ætheria, the freshwater oyster of the African rivers, has a large foot.

† Cryptodon has a long cylindrical tentacle-like foot, with no viscera extending into it, and the liver and sex organs in branched processes lying between the gills. The foot is pillar-like in Arca.

‡ Openings are found in Solen, Cardium, and many others.

a tongue-like process, grooved at its base, single or lobed, having part of the foot retractor, or a special muscle inserted into it as a retractor; the form of the threads depends on the grooves of the byssus organ, and we may find them each with a rind, and consisting of separate threads (Mytilus, Malleus, Dreissensia, Pecten), or with a rind, but not consisting of threads (Arca), or with no rind and its root broadly expanded (Lima, Meleagrina), or without an expanded root (Pinna, Perna). A byssus gland may exist in the embryo, vanishing in the adult (Unio, Cyclas). The shelly plug whereby Anomia is anchored seems to be of this nature, and a retractor muscle is attached to the plug. The foot and other parts secrete phosphorescent mucus in Pholas and Lithodomus. The foot is the organ of locomotion. Lyriodon has been seen jumping four feet high by its contraction.

The shell is closed by adductor muscles which pass transversely from one valve to the other; they are attached to scar-like muscular impressions conspicuous on each valve, and are usually two in number (*Dimya*); sometimes close together, or even fused (Tridacna). In Mülleria and Ætheria there are two adductors in the embryo and only one in the adult; others (*Monomya*) have but one (posterior) adductor. In Anomia there is a third muscular scar, hence the name *Trimya* has been given to it. The two in Dimya may be similar in size (*Isomya*), or form (*Homomya*) or dissimilar (*Heteromya*). Some, as Pecten, with small foot, swim by alternate closure and opening of the shell.

The heart lies in a part of the body cavity called the pericardium,* under the hinge line and above and behind the liver; it is lined by tesselated epithelium.

* Anomia has no pericardium.

On its upper surface are two dark-brown crescentic membranous folds, pierced by fine reticular openings, and surrounded by capillary lacunæ (the red-brown organ of *Keber*): these, with the ducts of the organ of *Bojanus*, serve as outlets from the pericardium. The heart has one ventricle with a spongy interior, traversed by the intestine; in Ungulina the latter only traverses the wall of the heart, and does not enter its cavity. In Arca the intestine splits the ventricle in two; in Ostrea, Anomia, and Teredo, the heart lies under, and is not pierced by, the intestine. Two auricles (one in Anomia)* receive the blood from the gills, and transmit it through a two-valved auriculo-ventricular opening into the ventricle, from the front of which arises the anterior aorta (see Fig. 31[e]),† whose branches supply the foot, mantle, anterior adductor, &c. In Anomia this vessel has an arterial bulb at its base. The ventricle gives off behind the posterior aorta (absent in Teredo), which passes between the foot muscles to the pericardium, organs of *Keber* and *Bojanus*, intestine, &c. The large vessels have coats and an epithelial lining, but end mostly in wall-less lacunæ; sets of true capillaries, however, having structureless walls with scattered nuclei, exist, as an erectile layer in the foot, mantle, and interbranchial septum, and as arborescent branchings on the intestinal wall. The blood is returned by veins, partly into the venous sinus, under the organ of *Bojanus*,‡ or into that organ itself, or directly into

* The two auricles unite in the oyster.

† In Arca each ventricle gives off an aorta, and the two unite to form a common trunk.

‡ This sinus receives one branch from the erectile tissue of the foot,

the auricle. In the organ of *Bojanus* the blood becomes mixed with water, and thence passes by channels (branchial arteries) to the gills, and is returned by sacculated bronchial veins into the auricle. The heart beats 5–10 times (Unio), or 20–30 times in a minute, and continues to act after the animal is taken out of the water. The sinus venosus and bloodvessels have no propelling power.

The gills are lamellar, placed longitudinally on each side between the mantle and the foot, having the free borders directed ventrally. They are usually symmetrical (except in inequivalve genera, particularly in Anomia), and in two pairs on each side (Corbis, Lucina, and many other Lucinidæ, have but one pair); of these, the external are the smaller and the later in development. Each gill lamella consists of two layers of comb-like* filaments, which are free (Arcidæ, Pecten, Trigonia, Spondylus), or united by horizontal bands into a continuous multifenestrated plate, supported on a framework of chitin rods, arranged in rows behind each other, and richly ciliated on the surface. The layers are more or less united, directly or by a connecting membrane. The inner gill lamella may adhere to the foot, leaving an internal branchial channel between them; the outer lamella may be unilaminar; the space between the gill-lamellæ is the interbranchial chamber. The ciliary

two from the viscera, and one from the mantle. Its blood is poured into the organ of *Bojanus*.

* A lamellibranch is aptly compared by *Keferstein* to a book whose back is represented by the hinge line, its cover by the shell valves, its fly leaves by the mantle lobes, its second and third pages at each side by the gill lamellæ, and its interior by the visceral sac and foot. In Anomia the sickle-like gills are removed from the visceral cavity, and do not extend as far as usual.

motion of the gills of marine bivalves is immediately checked by immersion in fresh water.

The organ of *Bojanus* is yellow or brown, spongy, bilaterally symmetrical, placed dorsally next the base of the gills, the lateral parts being sometimes medially united.

It is tubular, opening within into the pericardium by a radially lamellar extremity which surrounds the tendon of the posterior retractor, and lies on the front and lower surface of the hinder adductor; its central part is sometimes dilated into a spongy cavity; the outer part opens on each side into the mantle cavity. Into its spongy tissue the blood from the viscera enters by a portal system of vessels, and mixes with water, admitted by the duct of *Bojanus*. In its recesses in Lutraria and Mactra uric acid is found, and, in Pectunculus pilosus, granules of calcium phosphate. In Teredo this organ is a dark layer, containing urate of ammonia, overlying the auricle of the heart; in Ostrea it is also appended to the auricle close to the commissure between the epipharyngeal and visceral ganglia, and contains concretions. The sex organ opens into this organ in Pecten, Lima, and Spondylus, or the duct of the sex organ unites with its duct in Arca, Modiola, and Mytilus; in Pinna they open on the same papilla, but the sex duct is the farther back. The ducts are separate in Cardium, Chama, Pecten, Unio, &c. This is a modified segmental organ; its cavity is regarded by *Rolleston* as a water-vascular organ; its function is excretory, probably urinary.

The nervous system consists of—1st, an epipharyngeal (labial, cerebral) ganglion on each side, either remote and with a long commissure (Lucina, Arca, Mytilus, &c.), or close together (Venus, Mactra, &c.); or united (Teredo); this lies on the tendon of the retractor pedis anterior, and in front of the protractor pedis, above the mouth, and gives off on each side

labial, pallial and anterior branchial branches. The hypopharyngeal ganglion is united to the former by two commissures, one on each side of the digestive canal.

It is sometimes close to the first ganglion (Pecten), but is usually remote, placed in the foot, hence it is called the pedal ganglion (or, from its describer, the Mangilian). When the foot is small or absent, the ganglion is small or obsolete, as in the oyster; it is also small in Teredo. It sends branches to the retractors of the foot, to the adductors, to the body wall, but none to the viscera. From the epipharyngeal ganglion two lateral commissures pass backwards to the front of the hinder adductor, where they unite to form a visceral or anal ganglion, giving off a posterior branchial, and lateral and posterior pallial branches (the first of these branches in Ungulina has a separate ganglion on it at its origin). These ganglia are usually bright yellow, translucent, and contain round fat cells, small, colorless, medullary cells, and non-medullated nerve fibres. They are symmetrically disposed in equivalve forms, but are unsymmetrical in inequivalves. A few filaments from the epipharyngeal ganglion represent the labial nerves of Brachiopods. In Unifora there are two long circumpallial nerves along the margins of the mantle lobes; sometimes there are small ganglia along this line in Trifora, as in Solen.

As organs of sense, there are, 1st, labial tentacles; 2nd, marginal tentacles, supplied by the circumpallial nerve; thread-like in Lima, Pecten, &c.; thicker and contractile in Donax and Mactra, sometimes highly extensile (Lepton). In siphonate forms these are grouped about the mouth of the siphon. In Unio there are a few papillary tentacles at the hinder end of the mantle border. A siphonal ganglion supplies these in the siphonate forms; 3rd, otocysts exist, one on each pedal ganglion; they are oval, with a homo-

geneous basement membrane lined by ciliated epithelium, and filled with fluid, holding one or more globular otoliths, which during life rotate rapidly; they have either one nerve in each (Unio), or else they lie directly on the ganglion; sometimes they are deeply imbedded in the foot (Cytherea); 4th, eyes exist in the larvæ of all as pigment spots with a lens, seated on the head under the velum; these in the adult are lost, but secondary eyes develop as pigment specks, with neither nerves nor crystal cones, as the siphonal eyes of Solen and Mactra, or else as true eyes along the mantle edge, sessile or stalked, consisting of cornea, lens, crystal cones imbedded in pigment, iris with a movable pupil, and in Pecten and Spondylus there is a tapetum cellulosum. Into each eye in Pecten two branches from the circumpallial nerve enter, one into the fundus, and one into its side; these eyes may be from 8 to 90 in number, and are often brightly colored. The senses and psychic phenomena in lamellibranchs are of a low order, but a degree of memory is evinced if it be true that oysters taken from beds occasionally uncovered at low water never open their shells, while those taken from greater depths are more careless about the opening and closure of their valves.

Lamellibranchs have symmetrical, usually diœcious sexual organs, with no accessory apparatus; some (Ostrea, Pisidium, Pandora, Kellia, Galeomma, Cyclas, &c.), are monœcious. In Ostrea the ovigerous and spermigerous acini are mixed side by side in the one gland.* In Pecten varius the gland is bilobed, the

* But according to *Davaine* they are not functional together, but protandrous, the male acini reaching perfection when the females are unripe,

male lobe being above and in front, the female being below and behind, but the ducts are united, as in Cyclas. In Pandora the two lobes, now separate, have separate ducts, as in Clavagella. In the diœcious Margaritana, islands of ovary have been found in the testis. In Mytilus the gland is entirely overlapped by the mantle lobes. In Anomia it is in the under (right) lamella of the mantle. The gland is usually under and beside, often inseparable from, the liver (not so in Pinna), anterior to the hinder adductor, and in the side of the visceral sac. The genital opening, when separate from the organ of *Bojanus*, is on each side at the base of the abdomen. Kellia, Montacuta, and Galeomma are viviparous; in others the eggs are hatched in a gill pouch (Sphærium, Cyclas, &c.), or in the interbranchial chamber. Most bivalves are prolific; one Unio lays 3,000,000, and one oyster 600,000 eggs in a single season. The eggs have usually an albumen layer, thickened into a pillar-like process (micropyle) at one end; development begins by a rotation and cleavage of the yelk and the formation of a larva with a unilobar velum, often with a flagellum. The mantle (or in Cyclas the foot) is the first part to be developed, and the other viscera follow.

The 14,000 recent and fossil Lamellibranchs are divisible into two sub-classes:—

Sub-class 1. Endocardines—extinct, with rough reticulated shells, with unequal valves, the right attached to foreign bodies; umbones displaced from the margin to near the middle of the shell; ligament internal; hinge

so that according to season an oyster appears wholly male or wholly female. This statement has been called in question.

teeth on the free valve alone, allowing the valves to move parallel to each other; the mantle lobes uniforal, dimyary. These form one family (Hippuritidæ) and eight genera, from the cretaceous rocks, except the miocene Tamiosoma.

Sub-class 2. Exocardines—shell not reticulated; umbones smaller, marginal; ligament external; valve-opening hinge-like; teeth usually on both valves. This includes the following orders:—

Order 1. Monomya (*Lamarck*)—with one adductor, ligament nearly internal; mantle uniforal; hinge nearly or quite toothless, with one circumpallial nerve; no pallial sinus nor siphon, and an inequivalve shell. This includes the following families:—Anomiadæ, with unsymmetrical body, no labial palp, nor eyes; arched hinge line, obsolete ligament, and the under valve pierced for the calcified byssus; rarely free, with transparent shells (Placuna). Ostreidæ, with labial palps separate from the gills; foot obsolete; ligament internal in one conical groove; shells sessile; lamellæ rarely free (Ostrea), smooth (Gryphæa). Spondylidæ, with straight hinge line; ligament half-external; a triangular hinge area on the shell; teeth two, locking, rarely none (Pedum); foot small, pointed. Radulidæ, with gaping shells; long pallial tentacles; no ocelli; foot not byssiferous (with a byssus, *Stolicza*); hinge toothless. Vulsellidæ, with long compressed shells; narrow gills, much produced posteriorly, united together and to the mantle at their border; rectum simple. Pectinidæ, with no hinge area; mantle with ocelli; gills equal; foot small, cylindrical, sometimes byssiferous. The shells are auricled, usually regular, smooth (Amussium), or radially ridged (Pecten), rarely unsymmetrical (Hinnites). Aviculidæ, with terminal, not medial umbo, except in Crenatula; shells one or two-winged (Avicula), sometimes hammer-shaped (Malleus); foot small, byssiferous, for which one valve is grooved.

Order 2. Heteromya—muscular scars double, unequal, sometimes, as in Mülleria (fam. Ætheriidæ), becoming monomyary in the adult. The shells of the rest are usually equivalve, or nearly so, the ligament external; there are never lateral teeth, and the cardinals are weak; mantle uniforal (Pinnidæ) or biforal, with a wide pedal slit (Mytilidæ). This

family includes Mussels (Mytilus) without (and Crenella, Modiola and Lithodomus with) false siphons. Dreissensidæ—umbones terminal, each with a shelf-like septum, and a triforal mantle. Modiolarcidæ—triforal; with no septum in the non-terminal umbo.

Order 3. Isomya.—adductor scars two, equal or subequal on each valve: this order contains two sections:—§ 1. Integropalliatæ—pallial sinus none; shell regular, rarely gaping ventrally, with hinge teeth: this comprehends five sub-orders: 1st Arcaceæ—mantle edge free, rarely siphonate (Ledidæ); hinge teeth, many; cleft, symmetrical; foot large; its families are:—Arcidæ—uniforal; hinge teeth in a straight line; gills sub-pinnate; oral tentacles as processes of the gills; byssus present (Arca) or none (Pectunculus). Nuculidæ—hinge teeth serrate; shell anteriorly elongate; ligament internal. Ledidæ—labial tentacles long, convolute; siphons retractile; ligament internal (Leda) or external (Malletia). Sub-order 2. Trigoniaceæ—uniforal; hinge teeth v-like, diverging; mantle-edge with eyes; foot bent, for leaping; including one family mostly of fossil forms, ex. Trigonia. Sub-order 3. Unionaceæ (Naiades)—uniforal (siphonate in Spatha, &c.); one family of freshwater, olive shells with thick epidermis, nacreous within; foot not byssiferous (except Byssanodonta); embryos with at first only one adductor; cardinal teeth present, with (Unio) or without lateral teeth (Baphia), or absent, with (Barbala) or without laterals (Anodonta). Sub-order 4. Lucinaceæ—biforal (except Astartidæ); anal opening simple; foot cylindrical. The families are: Lucinidæ—equivalve; a branchial siphon; gills one pair; anterior adductor scar round (Corbis), double, (Cryptodon), or band-like (Lucina). Astartidæ—uniforal; gills two pair, with bearded edge; lateral teeth one or none; ligament in a groove (Crassatella), or external; foot rarely with a byssus (Mytilicardia); shell concentrically (Astarte) or radially ribbed (Cardita). Galeommidæ—byssiferous; an anal siphon; gills two pair; mantle edges projecting through the gaping shell. Leptonidæ—siphonal, byssiferous; foot ligulate or tapering; mantle with (Lepton), or without tentacles; ligament internal (Montacuta) or external (Lasea, &c.);

a long anterior mantle tube, open (Lasea), or closed below (Kellia). Ungulinidæ—foot hollow, worm-like, with a terminal erectile gland; four foliaceous oral palps. Sub-order 5. Chamaceæ—siphons short, separate; foot small or rudimental; shells unequal; inner gill pair small. The families are: Tridacnidæ—muscle-scars united; anus with tubular valve; outer gills unilamellar; shell thick, with (Tridacna) or without a byssus (Hippopus). Chamidæ—shells adherent, irregular, inequivalve, umbo spiral; two outer gill plates united behind; anal valve simple. Sub-order 6. Cyprinaceæ—often triforal; gills unequal; foot large. Families: Cyprinidæ—foot byssiferous; umbo spiral in Isocardia; epidermis thick; mantle open in front and below; siphons wide, short; teeth 2–3 cardinal and 1 lateral. Cyrenidæ—mantle open in front; margins simple; epidermis thick; hinge teeth 3.3 or 2.2; siphons diverging (Cyclas), or united (Pisidium). Cardiidæ—Cockles, pelecypodal; siphons short, sessile; shell equivalve, radially ribbed (Cardium), or smooth (Lævicardium, &c.

§ 2. Sinupalliata—pallial line with a deep sinus, mostly pleuroconchal. This includes four sub-orders. Sub-order 6. Veneraceæ—siphons moderate; mantle wide, open in front; foot large, pointed; gills four. The families are: Veneridæ—foot long, slender; siphons united at base or for the whole length (Dosinia); hinge teeth 2–3, with often a tooth under the lunula, but no other lateral tooth; a byssus in Tapes, not in Venus. Petricolidæ—foot with a byssal groove; siphons unequal, separate to their base; shells gaping posteriorly. Sub-order 7. Tellinaceæ—siphons long, fully separate; mantle wide open in front; outer gill lamellar, often rudimental; foot large. Families:—Paphiidæ—hinge cartilage present; siphons thick, separate from the base; foot tongue-like; shell close; pallial sinus small. Scrobiculariidæ—hinge cartilage present: siphons long, unequal; shell gaping behind; foot pointed, not high. Cumingia bores in coral, &c. Tellinidæ—hinge cartilage none; ligament strong, external; gills unequal; hinge teeth one or two; lateral teeth absent (Psammobia), or present (Tellina). Donacidæ—hinge cartilage none; shell wedge-shaped; siphons shorter. Sub-order 8.

Myaceæ—siphons long, united; gills not extended thereinto; shell gaping behind, with an inner hinge cartilage; shell and siphons covered with periostracum. Families:—Glauconomyidæ—mantle lobes open sufficiently for the protrusion of the keeled small foot. Solenidæ—body long; mantle open fore and aft; hinge anterior, terminal; byssus none. Saxicavidæ—elongate foot with byssus groove; cartilage small or none; pallial line interrupted (Saxicava), or continuous (Panopæa). Anatinidæ—quadriforal; hinge with ossicles; gills unilamellar, the one larger in Thracia being subdivided into two half lamellæ; shell with an outer layer of fine prismatic cells (Pandora, Mydora). Mactridæ—ligament internal; siphons united; labial tentacles long, pointed; foot straight; shell gaping (Lutraria) or closed; outer ligament separated from the cartilage by a shell ridge (Trigonella, &c.), or united to it (Rangia, &c.); mantle lobes separate (Mactra, &c.), or united (Lutraria, &c.). Corbulidæ—mantle lobes closed; cartilage in a spoon-like pit; oral palp small; siphons short, with cirri at their openings; foot with a byssus groove. Myidæ—mantle and cartilage as in last; foot not byssiferous. Sub-order 9. Pholadaceæ—siphons long, united; gills elongated into them; shell small, only covering part of the body, whose surface often secretes a calcareous tube; borers. Families: Gastrochænidæ—tube-dwellers; body clavate; shells small, equivalve; tube closed in front; shell valves free in the tube (Gastrochæna), or the left attached and the right free (Clavagella), or both fused (Aspergillum). Pholadidæ—body symmetrical; mouth-lobes long; foot short; hinge teeth none; siphons either bearing loose shelly plates at their end (the *palettes* of Teredo, the ship-worm), or with no *palettes* and rough, sculptured shells, as in the stone-boring Pholas. Kuphus has palettes, but no true shelly valve. Pholas has two triangular organs, covered with cilia, and containing fat and granular protoplasm, near the upper end of the mantle, which are the seats of its luminosity (*Panceri*).

CHAPTER XXXVI.

CLASS 2.—CEPHALOPHORA (*Blainville*).

OTOCARDIANS with a head, bearing sense-organs, and a mouth with, on its floor, a masticatory apparatus or *radula*, placed on an eminence partly muscular and partly cartilaginous; on this radula are transverse rows (joints) of irregularly shaped, but regularly disposed, teeth of conchiolin. Except in the first sub-class, the body is not fully covered by the mantle, which usually secretes a one-valved shell, often with a separate posterior, but not articulating portion. Three sub-classes are included :—

Sub-class 1. Scaphopoda (*Bronn*)—marine, diœcious, symmetrical forms, linking the next group to the bivalves; forming whitish, small, tubular, elephant's-tusk-shaped shells, concave dorsally, and open at both ends.

The shell is concentrically laminated, each new layer underlying its predecessor, and extending farther forward, with no periostracum, and thicker behind than before; its surface layer is homogeneous, on a prismatic stratum whose columns bend inwards and outwards alternately as in Patella; the lining vertically striated laminæ appears crenate on transverse section. The oldest part (narrow end) of the shell is often traversed by a fungus. Two or four oblique dorsal muscles (like the *columellaris* of Gasteropoda) attach the animal to the shell.

The mantle is thick in front, and has no outer epithelium nor glands, but many pigment specks and transverse ciliated folds; posteriorly it has a spoon-

like process, in front, many unequal sucker-like tentacles: its fore and hinder openings have sphincter muscles. The front of the head is joined to the buccal region by a narrow *pseudo-collum*. Eight radiating ciliated tentacles surround the mouth, into which two salivary glands, and two, ciliated, glandular, buccal pouches open. The buccal cavity is guarded in front by a valve, and contains an oval, wide radula of 25–30 joints, each of five plates, the median one-toothed, the inner lateral uncinated, the outer lateral unarmed; it lies on a tongs-shaped lingual cartilage whose branches are approximated below by one transverse adductor, and divaricated by two sheathing muscles. Two rudimental conchiolin-covered pharyngeal jaws oppose the radula. The œsophagus is short, the stomach gizzard-like, receiving the paired bile ducts; the glandular intestine has a primary neural flexure, and forms three folds under and parallel to the œsophagus, finally passing between the two organs of *Bojanus*, and through the anal sinus to its termination behind the foot. The liver is large, triangular, of one (Siphonodentalium) or two (Dentalium) lobes consisting of cæca lined by large, polygonal, coloured cells.

There is no heart, but the colourless blood accumulates in five, wall-less, lacunary sinuses, anal (the largest), post-abdominal, buccal, cervical, and pedal. From the post-abdominal sinus, it enters an anterior mantle vessel, forming a vascular ring, from which, and from the other sinuses, richly netted lacunæ pass into the mantle and foot, which act as breathing organs, there being no gills. The anal sinus has a pair of outer openings, one on each side of the anus, whereby water is admitted.

The foot consists of a central, obtuse, cylindrical lobe, hollowed at its base, and two lateral, symmetrical, wing-like epipodia. The organs of *Bojanus* are symmetrical, brown, compact, of many follicles lined by gland cells, lying on the rectum; they open into the hinder part of the mantle cavity, and the right receives the genital duct.

There are two pear-shaped epipharyngeal ganglia, joined by a long commissure in front of the buccal mass, and behind the pseudo-collum; from these arise two pedal commissures, two buccal, two tentacular, and four mantle nerves (inner and outer pair), as well as an azygos mantle-nerve. The hypopharyngeal (foot) ganglion is close to its fellow, gives off many (nine) foot nerves, and each has seated on it a spherical, ciliated otocyst containing many rapidly-moving otoliths. A pair of anal ganglia are attached together by a fine thread, and to the epipharyngeal by two filaments. Besides these are two anterior and two posterior sympathetic ganglia, joined by commissures, lying on the intestine. There are no eyes, but the animal retracts its foot if exposed to light.

The long, lobed sex-gland differs in the male and female only in the nature and colour of its contents, being white in the male, red and yellow in the female. It fills the entire (Siphonodentalium) or front (Dentalium) of the metasoma, and has no accessory organs. The eggs have shells, and form on stalked processes in the ovary; when impregnated, the yelk rotates, segments, and forms a ciliated gastrula, which elongates, and the external cilia form seven complete circlets, the foremost of which dilate into a velum, and the others vanish. On each side posteriorly a

scale-like shell forms as a partial bivalve investment; the three-lobed foot then forms, the shell valves unite, become tubular and elongated anteriorly.

The one family, Dentaliidæ, includes ten genera, of which Dentalium and Siphonodentalium have an entire-margined hinder opening. Antalis has the hinder opening with a deep side notch. Dentalium has a short, thick foot; in Siphonodentalium it is long and cylindrical.

Sub-class 2. Pteropoda (*Cuvier*)—small, active, marine, crepuscular, carnivorous forms, with rudimental head and sense-organs, and large epipodia, symmetrically developed as "fins," one at each side of the anterior end. These are composed of two or more layers of muscular fibres in a firm connective base, covered by tesselated epithelium, sometimes with rows of cilia (Styliola). By their rapid to and fro wavings, these fins act as swimming organs; rarely a second pair of linear fins lies behind the front pair (Cymodocea). The rest of the foot is rudimental, with separate elements. The propodium in Pneumodermon, Clio, &c., is elongated into retractile, lateral, circumoral processes, like the arms of Cephalopoda, armed with stalked or sessile (Spongobranchia) sucking discs. The mesopodium is often horseshoe-shaped, or both these parts may be absent (Cleodora). The metapodium in Limacinidæ bears a few-whorled, spiral operculum.

The mantle may be none, rudimental, or developed, secreting a shell on or in its texture, and this, with the mantle, may be persistent or lost in the adult (Cymbuliidæ). Its lobes may bound a cavity opening ventrally (Cleodora), as in Cephalopoda, or dorsally (Limacina) by a slit directed forward behind the epipodia. The shell may be of pure con-

chiolin; when calcareous it is rich in phosphates, and consists of a periostracum, a layer of vertical prisms bent a little at their inner ends, and an irregular granular layer within; in shape it may be of united dorsal and ventral valves, globular, acicular or spiral, sinistral in Spirialis, Limacina, Heterofusus, dextral in Cheletropus. There is a retractor muscle for the drawing in of the body. The shell-less forms have an integument of cellular connective tissue, with longitudinal (external) and circular (internal) muscular fibres,* containing calcareous grains, pigment cells,† and fat-secreting glands under a layer of cylinder epithelium.

The mouth is anterior, round, or slit-like, with or without lips; in Tiedemannia it is on a proboscis. There is a radula present (except, perhaps, in Halopsyche and Tiedemannia), whose base is retractile into a sheath; it is armed with five rows of teeth, an axial series bordered by two intermediate and two lateral rows. In Clione there are bundles of lateral teeth at each side of the mouth, whose bases are imbedded in muscular tissue. Clione and Pneumodermon have eversible sacs, one at each side of the radula, sunk in deep pits, and armed with recurved hooks; these can be protruded as prehensile organs.

The straight œsophagus has a crop-like dilatation in Tiedemannia, and ends in the oval or fusiform stomach, which has strong muscular walls‡, sometimes with teeth of conchiolin and longitudinal folds (Hyalea). The pylorus is at the centre of the length of the stomach, and the short intestine has first a

* Either smooth, homogeneous, of fused cells, or branched, stellate fibre-cells.

† Tiedemannia has stellate chromatophores, with or without muscular processes.

‡ Circular externally, longitudinal internally; with a connective basis and a ciliated lining.

neural flexure, except, perhaps, in Limacina. The anus is mostly lateral, near the front edge of the mantle, or in shell-less forms under the fin. The salivary glands are tubular cæca in Clione and Pneumodermon, rudimental or absent in others. The liver is large and lobed in Thecosomata, or as numerous yellow or green gastric cæca in Gymnosomata. These organs lie in a single or partly divided sac.

The heart, which is not rhythmic in action, lies in front of the visceral sac (Cymbulia), to its right (Pneumodermon), to its left (Limacina), or within it, and consists of an auricle with thin walls of branched muscular fibres, ciliated within, and a globular or pear-shaped ventricle of thick, transverse muscle, non-ciliated, having a double auricular, and one (Hyalea), two (Styliola), or no (Cleodora) aortic valve. The aorta sometimes begins in a bulb, and gives an anterior cephalic branch, traversing the nervous collar to the epipodia, and a posterior, visceral. The heart is in a thin-walled pericardium in Hyalea, Pneumodermon, &c. The arteries are thin-walled, and end in lacunæ, as there are no capillaries nor veins, unless the channel from the front of the kidney to the gill-shield in Styliola be considered as a vein. From the lacunæ the blood enters the auricle. The gills may be two, absent (Pelagia), or crescentic lateral folds in the mantle cavity (Hyalea), or a ciliated shield on the ventral side of that cavity (Styliola), or the lining of the whole or part (Limacina) of the mantle-sac, or external leaf-like appendages (Pneumodermon), or an outer terminal ring (Spongobranchia), or a median ciliary girdle (Trochocyclus). The excretory organ (kidney) is tubular, with one opening within the

mantle or beside the anus, and a second, surrounded by a sphincter, into the pericardium. This organ may be hyaline (Cymbulia, Clione), or thick, contractile (Styliola), or soft, spongy, and glandular (Hyalea, Cleodora). Beside it in Pneumodermon is a wheel-like ciliated body of unknown function.

There is a circum-œsophageal nerve-ring with two large, confluent, sub-œsophageal ganglia, joined by a commissure over the œsophagus; from these pass branches to the epipodia and to the body wall. A sympathetic ring with one or two pair of ganglia surrounds the intestine lower down. In Pneumodermon, Clione, &c., there are two or, usually, three, rarely four, pair of united ganglia, the hypopharyngeal bearing otocysts, with mulberry-like otoliths. These ganglia consist of oval or unipolar nerve cells. The head bears paired, large (Theceurybia), or small (Hyalea) tentacles, which are rarely seated on the front of the fins (Limacina and Styliola virgula), or absent (Halopsyche). There are three pair of feelers in Clione australis. Anterior feelers in Clionopsis are supposed, but without sufficient reason, to be olfactory. Eyes represented by pigment specks are found on the visceral sac of Hyalea. Similar masses with lens-like bodies lie on tentacle-like processes on the neck in Cleodora and Styliola acicula, &c.

The single, lobed, hermaphrodite gland lies behind the stomach and beside the heart in the visceral sac: its duct dilates into a seminal vesicle, receives the duct of an albumen gland, and a small *receptaculum seminis*, and then ends in a vagina, in front of which is the eversible imperforate penis. The outer part of the gland produces ova, the inner, spermatozoa; but

the two parts are not functional together. The ova completely segment, and produce rotating embryos, developing one, rarely three, ciliary circlets, the front one of which becomes a bilobed velum. This is lost as the foot and epipodia develop.

There are two orders, including twenty-three genera and ninety living species :—

1. Thecosomata (*Blainville*)—having a shell, an indistinct head, gills in the mantle cavity, and a 2–5 rowed radula. Families :—1. Hyaleidæ—shells inoperculate, symmetrical, subulate (Styliola), triangular, depressed (Balantium), internally septate (Triptera), or globular, with a lateral slit (Cavolina). 2. Thecidæ—Palæozoic, operculate, gill-less, with straight shell. 3. Limacinidæ—operculate, sinistrally spiral, turreted (Heterofusus), or helicoid, open in Eccyliomphalus. 4. Cymbuliidæ—shell internal; fin not retractile; gills none, ex. Tiedemannia, Halopsyche. The fossil families, Conularidæ and Tentaculitidæ, unite these to Hyaleidæ.

2. Gymnosomata (*Blainville*)—shell and mantle absent; head and foot distinct; larva with several ciliary zones. Families :—1. Clionidæ—gills none; epipodial lobes one pair; head with a pair of stalked eyes, three pair of head cones, and two (Clione), four (Clionopsis), or no (Cliodita) tentacles. The foot is rarely absent (Pteropelagia). 2. Pneumodermonidæ have external gills diversely placed as noted above.

CHAPTER XXXVII.

SUB-CLASS 3.—GASTEROPODA (*Cuvier*).

CEPHALOPHORA, whose bilateral symmetry is often hidden by the spiral coiling of the body. The undivided mantle secretes a shell which consists of one, two (rarely eight), pieces, antero-posteriorly, never laterally, disposed. The head bears 1–3 pairs of tentacles over the mouth. The foot is elongated, ventral, muscular, often fitted for creeping (their commonest mode of locomotion). This large class includes two types of structure—1st, water-breathing forms with a veliferous larva (Branchiata); and, 2nd, air-breathing forms whose larva has no conspicuous velum (Pulmonata). The former may have the gills behind (Opisthobranchiata), or in front of the heart (Prosobranchiata).

The skin consists of a cuticle-like epithelium, rarely ciliated entirely* (Phyllirhoë) in the adult, always so in the larva,† and a connective basement containing unstriped muscle; sometimes with clear, glossy, connective, or cartilage cells (Carinaria, Pterotrachea), often calcareous‡ concretions (Opisthobranchiata§), unicellular pigment glands (Pulmonata), and pouch-like mucous follicles,‖ as well as pigment

* Cilia are widely distributed in Opisthobranchiata. The cilia are most extensively spread where the gills are smallest. In others the cells are cylindrical.

† In Pontolimax a layer of cells underlies the cuticle like a deeper epithelial stratum.

‡ These often assume specifically characteristic shapes.

§ In Doris these make a form of dermal skeleton.

‖ In Elysia these are in pearly rows, and in oval groups in Gasteropteron.

cells, which are not acted on by muscular fibres (like the chromatophores of Pteropoda). Cnidæ, like those of Turbellaria, exist in clusters on the ends of the dorsal papillæ of Æolis and its allies. Bristles arising in follicles adorn the sides of some Chitons. The subcutaneous muscular lamina is not easily separable from the dermis, and usually consists of external longitudinal, and internal circular bundles of flat, anastomosing, unstriped fibres, not in separate layers (they are otherwise arranged in Æolidæ). These structures make up the body wall, of which two parts are generally differentiated—1st, the post-cephalic neural surface or foot; 2nd, the hæmal surface, which usually forms a mantle. The foot is usually flat, sole-shaped for crawling, and is then rarely divided.* In Heteropoda it is differentiated into three parts—pro-, meso-, and meta-podium—and forms a vertical swimming organ or fin, moving as a screw propeller. The upper and hinder edge of the foot may be prolonged into lateral lobes or epipodia, which may be elongated and wavy (Haliotis, Aplysia, Turbo), large and lobed (Rissoa), formed into lateral swimming fins (Gasteropteron), or as a pseudo-mantle (Doris). In Stylocheilus the metapodium is very long. The foot is a thickening of the body wall with well-developed longitudinal muscular fibres, often with large mucous glands.† The upper surface of the metapodium bears often a differentiated area, secreting a shelly structure,

* In Harpa, Ancillaria, Voluta, Oliva, the propodium is indicated by a transverse groove. In Strombus the pro- and meso-podium are marked out by grooves. A longitudinal groove divides it in Phasianella, and the two sides can move independently. Transverse grooves exist in Pedipes and Auricula brunnea.

† In Janthina these are large, and secrete the egg-raft.

the operculum.* The front edge has, in some, two lip-like, often glandular, processes. The foot is rudimental in Glaucus, or absent (Phyllirhoë, Vermetus, &c.), or its sole may be reduced to a sucker, as in the males of some Heteropoda.

The dorsal (hæmal) area of the skin behind the head usually forms a mantle with lateral folds, secreting from its surface, but not by special glands, a shell, but both disappear; shell and mantle may vanish early, and the dorsal integument may show instead, papillæ (Æolis†), or branched processes (Dendronotus), or cirri (Tethys). The mantle may be margined by a series of tentacles (Haliotis, Parmophorus); its edge is thick and muscular, frequently fringed with pigment-glands secreting the colours of the shell. The edge alone secretes the prismatic element of the shell. The surface secretes the nacreous lining. The shell covers the dorsal side of the animals, and is homologous with the pair of valves and ligament of a bivalve, or with the anterior valve of a Brachiopod; it may be of two kinds, either symmetrical, limpet-like (and then may have a slightly coiled apex, as in Calyptræa), or an inner shelf as in Calyptræa, Crepidula, &c., or a perforate apex as in Fissurella, or a hinder notch as in Emarginula. The aberrant Chiton shell is also symmetrical. In others the shell is coiled, and then may be globose (Natica), subglobose, oval, conical, subulate, fusiform, pyriform,

* In Harpa the metapodial lobes are large, and overlap the body shell. The dermal area referred to here is called the opercular mantle; it may exist without an operculum, as in Marginella; it may have a collar of tentacular processes round it (Turbo, Ampullaria).

† These bear cnidæ. No such weapons exist in the Proctonotidæ: but these have terminal openings to their papillæ.

discoid, auriculate, lenticular, &c. They may be coiled to the left (läotrope), rarely to the right (dexiotrope); in the former the mouth is to the right, and the shell is called dextral; in the latter to the left; hence the form is called sinistral. This may be normal,* but is often an abnormalty. Coiled shells are spirals of a peculiar modulus, resembling (and in Ammonites identical with) the true logarithmic spiral, usually differing in having a definite point of starting, and forming another geometrical species, the concho-spiral.† (In Argonauta, of the next class, the spiral is parabolic, *Heis*). In some cases the starting point of the spiral is at a certain distance from the centre, and the first whorl runs around a central nucleus with a definite radius (cyclocentric, concho-spiral).‡ In discoidal shells the shape is determined by the nature of the centre and the ratio of the progression, as well as the shape of the section of the chamber§ (which is constant). In most coiled shells,

* Clausilia, Busycon.

† If the width of the first whorl = the parameter of the spiral a, the spire in general = h, and the ratio of progression = p; then in the first whorl, $h = a$; in the second, $h = ap$; in the third, $h = ap^2$; in the mth, $h = ap^{(m1)}$. The radius (r) of the mth whorl $= r = \frac{a}{p-1}(p^{m-1})$. There may be two valves for p in the inner and outer whorls, when the spire is said to be diplo-spiral. This is the case in many gasteropods. My measurements lead me to believe that some land molluscs are triplospiral.

‡ The radius would then be $r = a + \frac{a}{p-1}(p^{m-1})$; if $a = \frac{a}{p-1}$, this becomes logarithmic as $r = ap^m$.

§ It was determined by the Rev. Canon Moseley that the geometrical form of this section was constant, so that the spire might be said to be produced by the revolution of a constant geometrical form around an axis, the producing plane being constantly increasing, but retaining its specific form throughout.

however, the generating figure as it proceeds slips down out of the original plane along a vertical axis, and the angle of descent is usually a constant one, and contributes another element to those necessary to be known to determine the shell form. This may be called the helicoidal co-efficient, and as its value for the last few whorls in multispiral shells may differ from its value for the earlier whorls, shells may be diplohelicoid as well as diplospiral.*

The shell consists of several strata of prisms, which vary in inclinations. It is lined by a smooth layer, not often nacreous. The mineral matter being biaxial in its behaviour to light, resembles Arragonite; it forms 82–99 per cent. of the shell, and gives it its heavy specific gravity (2.70–2.97) and hardness. The animal matter is conchiolin, and forms 0.82 – 8. per cent. In Cypræa, Turbo, &c., the shell is porcellanous, and in the former the mantle lobes are reflected over the outside of the shell, on which they secrete an enamel layer. Some shells contain phosphoric acid, magnesia, and iron oxide. *C. Schmidt* found the superficial mantle cells to contain a calcic albuminate, from which the shell substance is doubtless laid down. The periostracum (absent in Cypræa, &c.) may be pilose, silky, lamellar, or shaggy.

In coiled shells the smooth and porcellanous apex often differs in appearance from the succeeding whorls; it consists of the original shell of the embryo,

* The following classification includes all shell forms :—1. Spiral, including α, turreted; β, cylindrical; γ, short; δ, globular; ϵ, depressed; ζ, discoidal; η, convolute; θ, trochiform; ι, fusiform; κ, turbinate; λ, paucispiral; μ, multispiral; ν, ear-shaped. 2. Irregularly spiral. 3. Shield-shape. 4. Boat-shaped. 5. Conical. 6. Multivalve (Chiton). 7. Pseudocamerated (Euomphalus, Triton (Simpulum), corrugatum).

and is called the nucleus. The line of contact of successive whorls is the suture. The aperture at the end of the last, or body whorl, is surrounded by a variably shaped margin (*peritreme*), which may be circular, oval, semicircular, angular, spiny, or ridged, according to the shape of the mantle edge. The pillar along which the whorls are coiled is called the columella,* and it may be perforated below by a canal (Umbilicus), or covered by a thick shelly deposit (Umbilical callus).† The part of the last whorl overlapping the columella is the columellar lobe. The apex is turned backwards (except in Patella), sometimes breaks off in the adult, producing decollate shells (Subulina [Rumina] decollata, Urocoptis). The peritreme is entire in vegetable feeders, or its anterior end, or both ends, may be prolonged into siphons, which are formed by long, gutter-shaped processes of the mantle. In Typhis and Haliotis the shell is pierced by holes, corresponding to deficiencies in the mantle edge. The shell in some cases is rudimental, contained within the mantle (Limax, Parmophorus), and then it may be soft, or else glassy, like that of Cymbulia (Marsenia), or made of calc-spar-like material (Arion).

The operculum may be membranous, horny, or shelly, and usually is of the form of the generating plane of the spiral, and keeps itself geometrically constant by rotating on its own axis while revolving

* Rarely the whorls may be disjointed, as in Vermetus where there is no columella; or the entire wall of the chamber may be perfect without confluence with its contiguous neighbour, as in Scalaria where there is also no columella. In convolute shells like Cypræa the peritreme may run along the whole length.

† The shape of the shell may vary in the two sexes; the female shell having the last, or body whorl, wider than the male.

around the axis of the spire; its lines of growth thus mark its surface with a spiral which may be *multi-* or *pauci-spiral*,* according to the number of whorls. When the generating figure is a circle, then the operculum grows by regular additions all round, and is *concentric*. Other forms are called *imbricate*, *unguiculate*, *articulate* (when marked with processes). The operculum has always more conchiolin in its composition than the shell whose mouth it closes. In Pulmonates the side of the foot (not an opercular lobe) secretes a temporary covering, the *epiphragm* or *clausilium*, which is shed after hybernation is over; this is solid, consisting of calcium phosphate 86 per cent., and organic matter 6.5 per cent., but is not a true operculum. Litiopa, Rissoa, and Cerithidea are fixed by a byssus formed as a dried mucous secretion, but not from a special gland.

The body of a Gasteropod is divided into a prosoma and a metasoma. The former includes the head and neck, and to its under surface the foot is often united in front of the mantle edge. The mantle is only part of the differentiated body wall of the metasoma. The head in Opisthobranchs often bears a velum in the adult, and this may be lobed at its free edge (in Tethys forming a funnel): in Prosobranchs it bears tentacles, and often eyes, on stalks (*ommatophores*), or sessile. The mouth opens in many Prosobranchs at the end of a proboscis, which is a retractile part of the head, not an extensile portion of

* The number of whorls depends on the curve of the opening, and the consequent rate of rotation necessary to keep the operculum geometrically constant in shape. The spiral is usually dexiotrope. In Atlantidæ there is a läotrope shell, and also a läotrope operculum. The spiral is usually only seen on the outer surface (pagina externa).

the digestive canal. This is protruded by its circular fibres, and by means of its lacunæ becoming distended with blood; it is retracted by muscles attached not to its tip alone, as in the proboscis of worms, but to its whole extent. In some the proboscis is permanently partly protruded. A similar proboscis often exists in Heteropoda. The mouth is anterior, may be bordered by lips,* with a marginal sphincter, and leads into a buccal cavity, surrounded by a reddish muscular wall (sometimes with transversely striped fibres), forming an oval, buccal mass, in which are imbedded two or four true cartilages, forming an early example of an endo-skeleton. To these the muscles are attached, and they support the masticatory organs. These may be horizontally opposed lateral jaws armed with flat plates (Heteropoda, Paludina), or sharp teeth (Dolium), sometimes approximated (Marsenia) or united above, forming a vertical unpaired jaw on the upper pharyngeal wall, as in Pulmonata; but more commonly there is an inferior, unpaired, median organ (*radula*, *odontophore*, or *tongue*†) on a cartilaginous support, bearing on its surface teeth arranged in successive rows, each consisting of a middle or axial tooth (rachis teeth, *dentes*), bordered by one or more intermediate teeth (*uncini*) on each side, outside which are lateral teeth. The radula begins posteriorly in a sac‡ in the pharynx below the œsophagus, and is partially retracted thereinto. When not in use it

* The lips are fringed in some, as in Nubecula tulipa.

† The tongue proper is the eminence on the floor of the mouth supporting the radula, and containing one or two cartilages; it has a central cavity (cavum pulvinare), and a retractor muscle from the cartilage.

‡ The tongue sheath is variable, spirally wound and long in Patella.

stretches forward, and ends anteriorly by being attached by a globular, toothless portion (Orbis radulæ) to the floor of the pharynx. The teeth are of chitin or conchiolin, with calcic phosphate, and are true cuticular structures; they vary in number from ten (Pontolimax) to many thousands (Trochidæ); their forms and numbers are of taxonomic value.* The radula is absent in Phyllirhoë, Tethys, &c., as are the pharyngeal jaws in Aplysia, Tethys, &c.

In Doris there is a prehensile collar of two arched lancet-like conchiolin plates outside the buccal lips, covered with a file-like surface of close groups of bifid pointed warts. Pontolimax and Elysia have a prehensile, eversible sac appended to the tongue; in Pleurobranchus, Lobiger, Lophocercus, &c., there are two such side pouches in the buccal mass, attached in front and free behind, having long, outwardly-curved, slipper-sole-shaped, horny plates.

Into the mouth behind, rarely in front of the radula, open the ducts of the salivary glands, which are usually two long (Atlantidæ, &c.), or short cæca (Carinaria, Æolis, &c.), sometimes branched (Lobiger, Lophocercus, &c.), sometimes corkscrew-like (Voluta), or forked (Pleurophyllidia, &c.), very rarely. In Terebra and Polycera only a single follicle exists. In Phyllidia two lateral and one azygous. In Pleurobranchus there are three long, branched cæca reaching to the liver.

* The forms of radula are:—1. Gymnoglossa—toothless, as Acus. 2. Rachiglossata—with only rachis plates, as Volutidæ. 3. Hamiglossata—with rachis plates and one row of lateral teeth (Murex, Buccinidæ, Olividæ). 4. Toxoglossata—with no rachis teeth, but an intermediate and a lateral row (Conidæ and Pleurotomidæ). 5. Tænioglossata—with one row of rachis teeth and three lateral plates on each side (Strombidæ, Littorinidæ, Cerithiadæ, &c.) 6. Ptenoglossata—with no rachis teeth, and many lateral (Scalaria, Janthina). 7. Rhipidoglossata—with one rachis row, 4–6 intermediate and many small lateral rows (Neritidæ, Trochidæ, Haliotidæ). The paired jaws are also variable in Pulmonates, being absent (Agnatha), with a sharp tooth (Oxygnatha), striped with a crenated edge (Aulacognatha), or with marginal rows of teeth (Odontognatha).

There is one doubtful yellow gland in Conus, four in Janthina, Littorina, and Dolium, while in Murex the glands of both sides unite to a common duct, and in Umbrella one duct communicates with a large branched organ. In some the saliva contains free sulphuric acid, secreted by a special under lobe, which has a muscular investment.* This part of the gland is tubular; the rest is acinose.

A large muscle (*columellaris*) arises from the lower end of the columella in the body whorl of the shell, and is inserted into the operculum (hence it can shut the shell), into the foot, and mantle edge. In Pulmonates, where, as also in Fissurella, it is double and symmetrical, it sends off slips to the tentacles (*retractores tentacularum*) and to the buccal mass (*retractores buccales*†). It is crescentic in section in Capulus, and displaced to the right in Haliotis. Its size is generally proportional to the capacity of the shell; but in Pterotrachea, which has no shell, a corresponding muscle exists.

From the upper and hinder wall of the buccal mass passes the pharynx (lined by a reddish epithelium in some Heteropods), and the short, longitudinally folded and ciliated œsophagus, which opens sometimes into the middle of the stomach. It has a long glandular diverticulum in Lophocercus, or a crop, which may be pear-shaped (Elysia), saccular and unilateral (Tethys, Lymnæa, Planorbis, Buccium), or oval (Dolium, Cypræa, Voluta, &c.) A cæcal pouch, filled with

* Dolium Galea, Tritonium nodiferum, hirsutum, Simpulum corrugatum, Cabestana cutaceum, Semicassis sulcosa, Cassidaria echinophora, Phyllonotus trunculus, Rhinacantha brandaris, Aplysia camelus, Pleurobranchæa Meckelii, Pleurobranchus tuberculatus. In Dolium there is 0.4 per cent. of free H.Cl, and 2.7 per cent. of H_2SO_4.

† In Opisthobranchiata there are upper and lower pairs of protractors, and one lateral pair of retractors, for the buccal mass, separate from the columellaris.

gelatinous tissue and fusiform or stellate cells* (the Chiajean organ, or the organ of *Delle Chiaje*), opens into the œsophagus in some genera.

The stomach is usually simple, thin-walled, pouch-like, rarely four-angled, with four tooth-like projections (Pterotrachea), often with cæcal pouches projecting from it towards its cardiac or pyloric ends; its epithelium is columnar (Heteropoda), or ciliated in tracts, and often elevated into tooth-like processes (Telescopium), or lobular projections (Mitra). It is gizzard-like in Aplysia, with cartilaginous pyramids in its wall, and is lamellated with cartilage plates in Umbrella. The folds of its lining may be armed with hard epithelial cutting ridges (Tritonia, Scyllæa). In Philine the large stomach fills half the body cavity, and has three bony plates in its wall. Scaphander has similar three-sided plates with rounded angles. The beginning of the intestine in Aplysia, Tethys, and Pleurobranchus is dilated, in Aplysia, hidden in the liver, and is sometimes regarded as a third stomach. The intestine is short, ciliated, simple, and ends, usually forwards and on the right side, rarely posteriorly (Vaginulus, Onchidium), in an often wart-like anus, never lying in the respiratory cavity. Its wall consists of a muscular stratum, mostly of circular fibres, but with longitudinal intermixed, not in separate layers, often with oval, calcareous concretions freely scattered in it. The rectum is differentiated in Prosobranchs, and is often dilated and longitudinally folded within on the right side of the mantle cavity. The intestine is shortest in flesh-eaters like Buccinum, sometimes straight, with no flexure.† In Pulmonates

* Dolium, Murex, Buccinum, Voluta, Conus, Pleurobranchus.

† Apneusta, Phlebenterata.

and vegetable feeders like limpets it is long and coiled. A crystal style, like that of bivalves, exists in Bithynia, Strombus, Trochus, &c., in a pyloric cæcal pouch. The primary flexure of the intestine is hæmal in branchiate, neural in pulmonate forms. The anus has a sphincter, and in Purpura and Murex grape-like excretory glands open into it. Entoconcha, Rhodope, and some other Apneusta, are aproctous. The mouth and anus are never on the same medial plane, but in some Opisthobranchs the latter is mediodorsal. A transverse mesentery is only found in the last-named group. The few- or many-lobed liver surrounds the intestine in Prosobranchs and Pulmonates, slung by funnel-like threads in Tethys. In Heteropods it is deep brown, and mixed with the sex-gland, with one or more ducts, and often with concretions, as among Opisthobranchs.

In some of this latter division the liver has one duct opening to the right behind the kidney; in others it consists of a number of gastric cæca (Doris), or two lateral rows of brown intestinal diverticula, the ends of which may be within the body (in Pleurophyllidiæ and Rhodope scattered over the whole intestine), or in a side expansion of the body (Elysia), or in long papillæ on the dorsal surface (Æolidæ). These cæca are widened ducts, and resemble somewhat the branched canals of Dendrocœla. The ducts of these cæca may unite into a common pouch opening into the intestine, and this may be single, under (Dotonidæ) or over the ovary (Æolidæ), or double (Fionidæ), or three (Proctonotidæ). Detached elliptical (pancreatic?) follicles exist singly in Aplysia and Doris, a pair in Doridium.

The heart* is dorsal, rarely median (Doris), usually

* Absent in Entoconcha and Rhodope.

in a thin-walled pericardium,* in front and above the genital gland; it consists of one (usually) or two† auricles, always directed towards the breathing organs, and one round or pyriform ventricle, in some genera pierced by the intestine.‡ There are two, rarely one, auriculo-ventricular, and two aortic valves. The ventricular muscle is red,§ and its fibres pass in all directions, crossing its cavity as trabeculæ. The blood may be bluish, and richly corpusculated (Pulmonata) transparent (Heteropoda), rarely red (Planorbis), usually whitish opaline, and containing copper in some Pulmonates (*Harless* and *Wicke*).

The auricle is larger than the ventricle in Heteropoda, but is represented only in Abranchiates by muscular threads surrounding the inlet of the ventricle.

The ventricle gives off an aorta, which soon divides into cephalic and abdominal branches; the aorta, springing from a bulbus in Heteropoda, divides into corporal and visceral trunks corresponding to these, and the former divides into caudal and pinnal branches for the meta- and epipodium; and the caudal branch in Carinaria divides into two lateral branches and a medial penial artery in the male. These vessels in Pulmonates are white, being full of calcareous concretions. Where the rectum pierces the heart there are two aortæ (as well as two auricles), which unite, and then divide into the two primary branches. The cephalic aorta in Prosobranchs and Pulmonates gives off cerebral and pedal arteries.

* To which it is tied by fibrils in Prosobranchs; it is free in front of the visceral nucleus in Heteropoda.

† Two in Janus, Haliotis, Fissurella, Emarginula, Chiton, &c.

‡ Chiton, Nerita, Neritina, Turbo, Emarginula, Fissurella, Parmophorus.

§ Especially in Pulmonates; its fibres are branched and polynuclear in Heteropoda.

These vessels end mostly in lacunary spaces, either separate from (Patella) or communicating with the body cavity. In the liver, foot, some parts of the mantle, velum, and the intra-pericardiac wall of Aplysia, capillaries exist, which, in the last named place, form a rete mirabile connected to the aorta. In Haliotis the lacunæ are specialized, and, though wall-less, look like an intermediate form between lacunæ and true capillaries. From these lacunæ the blood returns to the heart either by slits in the pericardium (Heteropoda, Pontolimax, Actæonia, Elysia), or is collected in large spaces near the auricle (Abranchia), or enters venous trunks that bring it to the gills. There are no vessels in Rhodope nor Entoconcha, and none but the aorta in Pontolimax and Phyllirhoë; there are no veins in Opisthobranchiata. In Prosobranchs, anterior and posterior blood-sinuses, beginning by open ends, convey the blood to the branchial artery and to the kidney, where there is a close venous plexus, and whence comes a portal vein to the branchial artery and to the auricle.

There is a water-vascular system commencing by one* or more large, or several† small openings in the foot, with a network therein, and opening into the body cavity. Water taken in by these makes the foot large and prominent, while it mixes with the blood, dilutes it, and perhaps aerates it as well. In Dolium there is an opening into the vascular system beside the anus.‡ The respiratory organs may be absent (Abranchiata, as Rhodope), or the surface, with its superficial lacunæ, may be respiratory (Dermobranchiata, as Pterotrachea, Pontolimax, Phyllirhoë). In others the gills are either parallel plates or cylin-

* Pyrula, Strombus, Buccinum.

† Natica canrena.

‡ In Pleurobranchus there is a small opening behind the genital orifice leading to the stem of the branchio-cardial vessel, between the point at which it receives a branch of the circum-dorsal sinus and the auricle.

droidal processes, of which there are never more than two sets, and often one (the left) is rudimental.

Rarely are they symmetrical, as in Patella, Chiton, &c., between the foot and the edge of the mantle (Cyclobranchiata). In Haliotis the two gills are displaced to the one side. They may be in a special mantle cavity (Aplysia, Bulla, Prosobranchiata), into which a siphonal gutter, never a complete tube, may lead. The gills are sometimes uncovered when the mantle is absent (Gymnobranchiata), and then they may be as a row of dorsal papillæ (Cerabranchiata*), each of which has a separate circular muscular coat, and often a nest of cnidæ at the tip. In Scyllæa, Tethys, Dendronotus, &c., the dorsal processes are branched, tree-like, in two rows, and with no liver-cæca (Polybranchiata). Sometimes they form a dorsal circlet or wreath round the anus (Pygobranchiata, as in Doris, sometimes only half surrounding it, crescentic, as Heptabranchus). In most Heteropods the gills form a cluster of thread-like or leaf-like organs near the point of the nucleus and beside the heart, between the anus and ciliary organ (Pterotrachea); sometimes they lie in a mantle cavity within a shell (Atlantidæ). In this group the gills are simple enlargements of the body wall covered with a thin dermal and muscular layer, with no proper branchial vessels (Nucleobranchiata), whereas in the others the gills are special organs. In Elysia, &c., the gills are flat lateral expansions, sometimes radially folded (Placobranchiata). In some of these Gymnobranchiate forms the axis of the gill stem has a firm elastic skeleton, composed of a double row of flattened hollow globules piled on top of each other. In the shell-bearing Opisthobranchs and in Prosobranchs the gills lie under the mantle lobes, and may be symmetrical on both sides (Dipleurobranchiata), or obsolete on one side (Pomatobranchiata). In the last form the shapes of the gills are very variable, and there may be one (Umbrella), two, or three branchial veins to the auricle, with or without special walls. In Prosobranchs

* The lateral appendages of Dorideans (Ancula, Triopa) are not branchial, but only dermal processes.

they may be leaf-like or like a row of threads (Patella), in a collar or in a pouch (near the cavity) at the dorsal side of the body whorl, bounded beneath by the body wall, above by the mantle, and behind by the union of the two: on the floor of this cavity is the vagina, or the seminal groove; between this and the anus is the opening of the kidney. The mantle may be bi-lobed and a gill pair present (Haliotis, Vermetus, Magilus, Conus, Pleurotoma, &c.) In Strombus, Natica, Modulus, only a slight band, as long as the right gill, marks the place of the left gill. This rudiment is broad in Cassis, short and triangular in Cypræa, absent in Sigaretus, Pteroceras, Calyptræa, Littorina, Nerita. In Janthina and Valvata the long gill filaments protrude out of the mantle cavity. The gill shapes usually vary with the shell shapes. In Turbo the gill cavity is divided, and each gill lies in a separate space. This is imperfectly the case in Phasianella.

Passage forms from the branchiate to the pulmonate division occur in Ampullaria, where the wall of the mantle cavity at certain places shows large vascular plexuses coexisting with the gills. In the Neurobranchiata the same arrangement occurs, but the gills become obsolete. The presence of a siphon in most of these shows their affinity to Prosobranchs. In the pulmonates proper this part of the mantle cavity is shut off from the rest as an air-chamber, and has a muscular wall, a narrow mouth with a circular sphincter; rarely dermal gill-processes coexist, as in Onchidium. Ancylus and Acroloxus have no pulmonary cavity separate from the general mantle cavity. The aquatic Limnæa uses its air chamber as a float.

The kidney is single, white or yellowish, lamellar or spongy, often containing uric acid, and consisting of an internal part opening into the pericardium, and an external, opening near the anus.

In Pulmonates it lies between the pulmonary vein and the heart; in Prosobranchs between the gills and the heart, in the floor of the gill cavity close to the beginning of the intestine. In Actæon and Phyllirhoë it appears as a long clear pouch; a pair of similar pouches are present in the embryo of Ancylus. Its outer opening in Prosobranchs is often duct-like, usually has a sphincter, and often radial dilating fibres. In Heteropods this organ contracts rhythmically, like a heart, and is supposed to force water into the blood, and to act as a portal heart, propelling the venous blood which it receives into the heart. In Carinaria it has a lining of gland-cells, as in Prosobranchs. In Opisthobranchs there are four types of kidney:—1st, single, as in Prosobranchs (Phyllirhoë); 2nd, with its inner part differentiated as a portal heart, sending blood into the pericardium and gills, the outer part remaining glandular (Fiona); 3rd, the portal heart developed, while the renal part is obsolete (Janus); 4th, the outer glandular part dissevered from the portal heart, which is often absent (Doris).

Other accessory glands are the purple glands in the wall of the mantle in Dolabella, and over the whole surface in Aplysia, or beneath the intestine in the mesentery; the depilatory glands in Aplysia at the bottom of the right swimming fold; the foot gland in Slugs (*Kleeberg*) a cluster of unicellular glands near the inner surface of the foot.* In Geomalacus and Arion there is a similar tail gland. In Prosobranchs transverse leaf-like mucous glands lie often on the roof of the mantle cavity. In Fiona two large glands, whose function is unknown, lie in the body cavity beneath the stomach, and open under the mouth. Pleurobranchus tuberculatus has surface glands at the base of its dorsal warts.

The nervous system consists of a pharyngeal ring with a pair of eyes, and a pair of hypo-pharyngeal

* To get rid of the mucus in the dissection of Slugs and Snails, *Gulliver* recommends drowning them under an inverted tumbler filled with water and placed in a basin. For marine Molluscs the best method of preparation is to kill the animal with vinegar, then to open its visceral cavity by a long slit, and immerse for an hour in spirit of wine before dissecting.

ganglia: the upper are the cerebral ganglia; the lower the pedal, behind which lie two parietosplanchnic ganglia; these are all joined by commissures (called respectively *commissuræ cerebralis*, *pedalis*, *visceralis*, *cerebro-pedalis*, and *viscero-pedalis*), and the ganglion cells are often red or yellow. The epi- and hypopharyngeals of each side may approximate, and may even fuse, while the upper is often divided into two—an upper, or brain, and a lower, or branchial ganglion, or the epipharyngeals may unite and form a single-lobed nerve (Heteropoda). As a rule, the higher the animal the greater the degree of coalescence.

Derived from the epipharyngeal, and on its primary branches in some Opisthobranchs, there may be tentacular and branchial as well as cerebral ganglia, and from the pedal ganglia come off branches to the m. columellaris. The brain ganglion gives off branches to the tentacle, eye, olfactory organ, ear, and penis. These commissural rings derived from these ganglia in some Opisthobranchs surround the pharynx, on the anterior of which are two buccal ganglia, united by a commissure or fused into a bilobed ganglion in Littorina. Each ganglion consists of unipolar, rarely bipolar, cells in a neurilemma, which in Pulmonates (Zonites Algira) has been shown to contain involuntary muscle fibres.

The tentacles are absent in Chiton, two in most Prosobranchs, or four in others—one pair often specialized for the support of the eyes (*ommatophores*). In these the nerves end in a ganglion, from which pass fine filaments, ending in stiff surface bristles (Trochus); they are covered by ciliated epithelium. Between the tentacles of Phasianella and in front of them is a median head lobe. A tentacle may spring from the foot, as in Buccinum, Harpa, &c., in front or

behind. Tethys and other Opisthobranchs have a velum moved by separate muscles.

The eyes rarely absent (Chiton, Vermetus, Janthina ?), are seated either on the summits (Helix, Terebra), middle (Murex, Conus), or bases (Littorina, &c.) of ommatophores, or else are sessile (Opisthobranchiata). In Strombus the ommatophores bear flagelliform tentacles. The eyes are globular or oval, covered with a cuticular cornea, a firm lamellar dermal sclerotic, lined with a pigmentary choroid layer, which is continued in front as an iris. The bilaminar retina consists of crystal cones, fibres, and granules, spread on a vitreous humour, in front of which is embedded a lens.

The eyes are most complex in Heteropoda, enclosed in irregular eye capsules, which freely communicate with the body cavity. There is also a protractor and a retractor muscle for the eyeball in some (Pterotrachea), in which also the retina has a vesicular layer under the rods. In some Prosobranchs the optic nerves are united at their origin. In Pulmonates a layer of pigment separates the two laminæ of the retina. In Opisthobranchs they are rarely in front of the bases of the tentacles (Aplysia, Dolabella), and are sometimes far apart (Haminea). Neither tentacles nor eyes are ever seated on the proboscis. The optic nerves often form a ganglion behind the eyeball.

The sense of smell may be seated in the tentacles of Nudibranchs, which are lamellar, screw-like (in Janus), or branched. In some there are radiately folded ciliary surfaces, like the wheel organs of Pneumodermon. In Pulmonates this sense is probably seated in a large lobate grey organ on each side of the mouth, in contact with the skin, and only covered by epithelium: within are many nucleated cells, and over its surface is a shallow groove (organ of *Semper*). The ciliary organ of Heteropods is probably sensory, but of un-

known function, seated in front of the nucleus and under the anus, not far from its opening; it is strongly ciliated, with swollen borders and hair-like nerve endings.

The ears are paired, round vesicles, usually behind the eye, close to the foot ganglion, rarely to the epipharyngeal (Œolidæ, Abranchiata, Heteropoda). They are generally in contact with the nerve centres, more rarely on the end of a nerve (Heteropoda), or the vesicle may have a stalk reaching to the foot ganglion (Neritina, Elysia). There are often many otoliths (100 in Pleurobranchia, 40 in Doris), which are sometimes pillar-like and arragonitic, sometimes only one and lamellar, as in Martynia, Tergipes, Rhodope, or mulberry-like (Phyllirhoë). In Paludina the ear sac is movable by muscles. The otocyst is ciliated within, but the cilia disappear in old individuals of some species. The nerve sometimes enters the sac in two or three filaments. A tube leads from the surface to the otocyst in some Pulmonates. A sympathetic system exists in the form of a pair of œsophageal ganglia joined by a commissure, with other posterior visceral ganglia in pairs.

Prosobranchs are usually diœcious: Pulmonates and Opisthobranchs usually hermaphrodite. In Opisthobranchs most commonly all sex products are formed in one set of follicles in a hermaphrodite gland, or there may be separate male and female follicles in the one gland, or separate glands in the one animal. The reproductive organs are usually on the right side, in the post-abdomen, seldom separate from the liver, and there is a common duct widening into a uterus, with which communicates a gland for the secretion of the nidamental capsule in which the egg is laid. The

arrangements of the ducts are liable to vary,* and to them may be appended receptacula seminis† and nervous glands, with clear and opaque cells.‡ The penis is protrusible like a glove-finger, sometimes spirally rolled when not in use. In Pulmonates there is always a multilobar hermaphrodite gland, often with cæcal processes (Limnæa), with an often tortuous hermaphrodite duct ending in a double tract, the female product escaping by an oviduct into a dilated uterus, below which is a pouch-like *receptaculum seminis* and an albumen gland; the female organ ends in a vagina. The male duct begins as a ciliated groove,

* The varieties are as follows :—A. Genital gland branched, diffused in the body.

I. Male and female glands separate, with a branched prostate, and both ducts far forward = Elysia (Placobranchiata) [Pagenstecher describes Elysia as having a hermaphrodite gland].

II. Male and female glands not separate, but distinguishable; prostate diffused; vagina far back = Pontolimax (Abranchiata).

Male and female glands not separate, but distinguishable; prostate unknown, all sex ducts united = Tergipes (Gymnobranchiata).

III. Male and female glands united; prostate simple; follicles separate = Rhodope (Abranchiata).

Male and female glands united, prostate simple; follicles hermaphrodite = Phyllirhoë (Abranchiata).

B. Genital gland consolidated behind the liver; prostate simple.

IV. Male and female ducts at first united, then separate, ovarial, vaginal and seminal openings close in a cloaca = Fiona, Facelina, Tethys, Doris, Dendronotus, Pleurobranchus, Pleurobranchæa.

V. Male and female ducts united for a long extent, with no inner canal to the penis; genital openings separate, but close together = Pleurophyllidia, Umbrella.

Male and female ducts united for a long extent, with no inner canal to the penis; penis far in front of the vagina, with a ciliated canal = Aplysia, Doridium, Gasteropteron, Philine.

† Described as the Swammerdamian vesicle.

‡ Umbrella has a cæcal pouch between the vagina and uterus.

and has appended to it a multifimbriated prostate. The end of the vas deferens is muscular, elongated as a penis often with a long flagellum. The spermatozoa are united by albuminous matter into masses or spermatophores. In Helicidæ there is appended to the male organs an eversible sac, whose papillary mouth is close to the opening of the mucous glands; within this the epithelium is calcified into a sharp quadrangular *dart*, varying in shape in different species. This is everted, and is used previous to the mutual impregnation of two individuals as an organ of irritation. Its use lasts about two hours in a snail, and is followed by a 5–7 minutes' impregnation. In Limax the two individuals twist spirally round each other in coitû. Self-impregnation has only been noted in Tergipes Edwardsii, and Limnæa auricularis, in the whole class.

Fig. 33.

Reproductive Organs of Helix hortensis :— *a*, hermaphrodite gland; *b*, duct; *i*, penis; *f*, fimbriated prostate; *h*, vas deferens; *c*, albumin gland; *d*, receptaculum seminis; *g*, dart sac; *e*, uterus.

Heteropods are diœcious: the penis of the males is a projection of the body wall with no sac, but with a glandular extremity, on the right side; and in Pterotrachea a mesopodial sucker is added. The lobed testis occupies the hinder part of the nucleus, and from the opening of the vas deferens a ciliated groove leads to the testis. In the females there is an ovary in the same position as the testis (often only distinguishable from it by its contents), an oviduct, albumen gland, uterus and vagina. Prosobranchs are mostly diœcious (except Chiton and Valvata). Some (Cymba, Littorina, Paludina), like the Pulmonates Plicaphora ventricosa, Clausilia similis, Pupa umbilicata and marginale, Helix rupestris, and some species of Achatinella and Vitrina, are

viviparous. Fixed forms, like Vermetus, are impregnated by the diffusion of spermatozoa in the surrounding water. Chitons alone have symmetrical ducts, and a median ovary lying on the aorta. They have rarely any appendages except a penis, often placed on the right side of the head below the eye. The ovary is embedded in the liver, and has a tortuous oviduct. Neritina and Paludina have accessory albumen glands, and its uterine wall secretes myelin. There may be a prostate in the male (Natica), often a vesicula seminalis. The penis is absent in Trochidæ and Scutibranchs; in others it is present, and has a claw-like appendix in Dolium and a penial gland in several other genera.

The eggs are laid usually in chains or in gelatinous masses, or contained in nidamental capsules. The masses may be (*a*) irregular, with the capsules fixed one to the other (cohærentes), dehiscing by a slit or by a round operculigerous opening; or with the capsules in a common membrane attached to foreign bodies (adhærentes). These may dehisce by a slit, or by a round opening, and the capsules may be sessile,* or stalked, cyathiform, oviform, or funnel-shaped; otherwise, they may be in (*b*) regular masses, coherent or adherent, with a central axis of attachment, as in Pyrula, on which they may be sessile or stalked.

The eggs are sometimes large, with calcareous shells (Pulmonata); the yelk undergoes total cleavage, and the body is built of the peripheric cells of the blastoderm. The larva develops a velum and ciliary circlet, and beneath the velum forms the mouth, intestine, and anus. The foot begins as a ciliary process below the mouth, and then the mouth and shell form, then the ear cysts appear, afterwards the tentacles and eyes; the anus, at first terminal, becomes anterolateral, and the embryo becomes free-swimming.† The shells of the

* Purpura capsules contain from 30 to 150 eggs, but only one usually reaches perfection.

† In a Prosobranch larva there are four stages:—1st. From the beginning of rotatory movement to the formation of a general ciliary clothing. 2nd. To the formation of a velum, foot, mantle, and shell. 3rd. The development of the first spire of the shell, of the heart, and the primary

larvæ (nucleus, p. 285) differ considerably in some cases from those of the adults. In Opisthobranchs the larval shell and mantle often disappear; in Marsenia the larval shell (Echinospira) is lost, and a new one developed.* In the embryos of some slugs there is a pulsating caudal sac (in Limnæa two sacs), which seems to keep up a circulation; this is lost in the adult. In Pulmonates the larva has no conspicuous velum, but a homologous structure exists, and often persists in the adult, as in Limnæa; on the left side of the neck in this genus a primitive *f*-shaped kidney of round cells and connective tissue is developed. They have also a cervical umbilical vesicle of stellate and fusiform cells and fibres. Some are very prolific. Dendronotus Ascanii has been calculated to lay 25,000 eggs annually, and a S. Atlantic Doris 600,000.

They are mostly marine. A few are fixed; but most move by crawling, rarely by swimming (Thetis, Œolis, Glaucus, &c.) Entoconcha is parasitic; Montacuta striata lives on Spatangus purpureus; many species in cold climates hybernate; Helix Hauffenii, and zoospeum live in caves, and are eyeless.

The sub-class is divisible into two orders, Branchiata (Branchiogasteropoda) and Pulmonata.

1. Branchiata—respiration aquatic; larva with a conspicuous velum; intestine with a hæmal flexure or straight. This includes the following sub-orders:—

1st. Abranchiata—separate gills none; surface ciliated; rachiglossate; larva with a shell which is soon lost. The families are, Pontolimacidæ—body flat; foot broad; tentacles filiform or none (Rhodope),† or as two, lateral, head crests (Pontolimax); anus dorsal. 2. Phyllirhoidæ—free swim-

flexure of the intestine. 4th. The loss of the velum and full development of the mantle, radula, &c.

* Larvæ of this class have been described as distinct genera: thus Macgillivraya is the larva of Dolium, Cheletropis of Murex, &c.

† This, the lowest Gasteropod, has no eyes, mantle, heart, nor tentacles. The tentacles are thread-like in Cenia and Dermatobranchia.

ming; footless; anus lateral, right; tail thread-like (Acura), or flattened (Phyllirhoë).* 3. Elysiidæ—placobranchiate; jaws none; anus dorso-lateral; tentacles ear-shaped (Elysia), or club-shaped (Placobranchus): probably the aberrant gelatinous Pterosoma, with no proboscis, foot, gills, radula (?) nor tentacles, sessile eyes, and lateral, fin-like folds, should form the type of a family.

Sub-order 2. Opisthobranchiata (*Milne Edwards*)—gills exposed or slightly covered, behind the heart;† hermaphrodite; larva shell-bearing; mostly carnivorous; gelatinous, full of sea water, which they discharge rapidly on being caught. When a shell exists in the adult it is inclosed in a duplicature of the mantle. This includes the following sections:—

§ I. Cerabranchiata (p. 294):—Family 1. Hermæidæ—genital ducts separate, rachiglossate; tentacles none (Alderia), or two contractile thread-like (Stiliger), or longitudinally folded (Hermæa). 2. Æolididæ—rachiglossal; tentacles not retractile; foot rudimental (Filurus‡); small (Chiorœra), or large; gills on foot-stalks (Calma), or on sub-pallial expansions (Fiona), or on the back; head tentacles none (Calliopæa), or four (Æolis).§ 3. Glaucidæ—gills on lateral pedicles; foot none. 4. Dotonidæ—tentacles retractile into a sheath; gills muricate (Doto), or smooth (Gellina). 5. Proctonotidæ—ptenoglossal; liver diffuse; tentacles simple (Proctonotus), or pectinate (Janus).

§ II. Cladobranchiata—gill papillæ branched or leaf-like. 6. Heroidæ—tentacles not retractile; teeth 2. 1. 2, and a labial veil between the tentacles. 7. Tritoniadæ—tentacles retractile; liver simple (Tritonia).‖ 8. Melibæidæ—teeth ∞. 1. ∞.;¶ liver diffused; tentacles retractile, linear (Melibæa), or lamellate; gills tree-like (Dendronotus), on three

* Sometimes infested by a parasitic gymnophthalmatous medusa, Mnestra.

† The heart beats in some 50-96 times per 1″.

‡ This genus has a ringed abdomen.

§ Æolis (Flabellina) punctata and Dendronotus arborescens emit sounds apparently by ejecting water, but this does not disturb the surface of the water in a basin.

‖ T. Hombergi grows to 1-1½ feet long. ¶ In Scyllæa 24. 1. 24.

little dorsal eminences (Nerea). 9. Tethyidæ—tentacles as last; tongue and radula none.

§ III. Pygobranchiata—dermis spiculigerous. 10. Onchidoridæ—gills retractile, in separate cavities; semilunar (Heptabranchus), or in a circle (Hexabranchus), or in two lobes (Villiersia); skin stiff, spicular (Onchidoris), or soft. 11. Triopidæ—gills retractile in one cavity; teeth 8. 0. 8 (Triopa), or 2. 1. 2 (Idalia). 12. Dorididæ—gills retractile (except in Acanthodoris), teeth numerous, equal; mantle weak (Casella), none, or well developed, with the body depressed, rounded above (Doris), or angular (Goniodoris).

§ IV. Pleurobranchiata (Mono-, or Di-pleurobranchiata)—gills covered by the mantle edge on the right or on both sides, the first sub-section including the following families:—13. Runcinidæ—shell-less, slug-like, marine; a shelly gizzard. 14. Pleurobranchidæ—shell internal, asymmetrical (Pleurobranchus, &c.), or none (Pleurobranchæa, Neda); genital openings close together; tentacles free. 15. Umbrellidæ—shell external, discoidal; apex subcentral; eyes intertentacular; head in a pre-pedal fissure (Umbrella), or projecting (Tylodina). 16. Lophocercidæ—shell coiled, unsymmetrical; side lobes of foot undivided (Lophocercus), or lobed (Lobiger). 17. Aplysiidæ—tentacles ear-like; stomach gizzard-like; foot with lateral lobes; teeth ∞ . 0. ∞ ; shell internal, calcareous (Dolabella), or subcartilaginous (Aplysia)*, or none (Bursatella, Notarchus, &c.). 18. Philinidæ—shell subspiral or none (Posterobranchæa); foot borders reflected round it; gizzard with calcareous plates; teeth 1. 0. 1 or 2. 1. 2; tentacles none, or adherent, as in the succeeding four families; foot rudimental, with two lateral epipodia (Gastropteron), or large; shell forming a complete whorl (Philine). 19. Bullidæ—frontal lobe quadrangular; eyes sessile; teeth ∞ . 0. ∞ ; shell involute, making a half whorl (Smaragdinella), or less (Cryptophthalmus), or one or more whorls (Bulla, Atys, &c.) 20. Cylichnidæ—shell perfect, with an elevated spire in Tornatina; teeth 6. 0. 6; head disc with lateral lobes.

* The purple secretion of Aplysia contains iodine. The secretion of its depilatory glands sometimes urticates the hand.

21. Aplustridæ—shell perfect; lateral processes of head lobes ear-like; teeth 13. 0 13. 22. Actæonidæ—shell perfect, operculigerous, involute: teeth ∞. 0. ∞ or 12. 0. 12. The shell-less Dipleurobranchs include (22) the toothless Phyllidiidæ, and (23) the jaw- and tongue-bearing Pleurophyllididæ, with lateral anus.

Sub-order 3. Heteropoda (*Cuvier*)—diœcious, marine, translucent; foot compressed, fin-like; shell thin or none; viscera in a nucleus; gills pectinate or filamentary; propodium vertical, fin-like; mesopodium suctorial in the males of some, the sucker having special circular and radiating fibres.* Family 1. Pterotracheidæ—body long; nucleus small, often stalked, naked (Pterotrachea, Firoloidea),† or with a shell (Carinaria and Cardiapoda); gills tufted, pre-nuclear; tentacles none (Pterobranchea), or present. 2. Atlantidæ, shell discoidal, spiral, operculigerous, into which the animal is retractile.‡

Sub-order 4. Prosobranchiata (*Milne Edwards*),§ including shelled Gasteropoda, which have the gills in front of the heart, and a veliferous larva. The visceral cavity is large, and the body nearly symmetrical. The following sections are included:—

§ I. Polyplacophora (*Blainville*)—chitons depressed, ovate, with a broad foot and a shell of eight valves. The mantle border is smooth or with excrescences; monœcious (*Middendorf*); cyclobranchiate; teeth 4–6. 2. 1. 2, 4–6 on a long radula; intestine straight or coiled; anus posterior, median; tentacles brain and eyes none; heart medio-posterior, elongated; sex organs paired, with two openings. The shell in Cryptoplax, &c., is imbedded in the mantle. The anterior and posterior valves are semicircular; the six intermediate have each three

* And between these are long radial glands.

† The larva of this genus has two gizzard-plates in the stomach. The peculiarities of Heteropods come out late in Embryogenesis.

‡ Bellerophon, Eccyliomphalus, and Cyrtolithes are fossils allied thereto.

§ The number of species in each group of Gasteropoda is as follows:—Opisthobranchia, 825 living, 335 fossil. Heteropoda, 54 living, 191 fossil. Abranchiata, 25 living, none known fossil. Prosobranchiata, 8600 living, 5670 fossil. Pulmonata, 5800 living, 530 fossil—in all, 21,980.

facets, a posterior flat pyramid with an umbo, and a pair of lateral areas; each of these consists of a *tegmentum* under the epidermis; free between the mantle edge, and an *articulamentum*, deeper layer; there are two pair of joints, *articuli antici* and *postici*, along the edge of the lateral areas. There is but one family.

§ II. Cyclobranchiata(Docoglossa)—Limpets, with conical, inoperculate shells; tentacles two, with eyes at their bases; foot large and flat; radula with no middle plate, and ridged lateral and intermediate plates. This includes the family Patellidæ, with a long radula; teeth 2. 4. 2; muscular impression on shell crescentic. The gills surround the head (Patella), or may be interrupted there (Nacella). Lepetidæ have no eyes nor gills. Tecturidæ have a free gill on the right side of the neck.

§ III. Aspidobranchiata — herbivorous, rhipidoglossal; shell conical, spiral, flat or cap-like; foot large; gills double; penis none. This includes—1. Fissurellidæ—foot large; shells flat (Parmophorus) or limpet-like, with an apical (Fissurella) or pre-apical (Rimula) opening, or an anterior marginal fissure (Emarginula).* 2. Haliotidæ—shells ear-like, nacreous within, left border with a row of holes along the suture; an anal siphon. 3. Pleurotomaridæ—conical, fossil shells, with a notched mouth, represented now by Anatomus and Stomatia. 4. Trochidæ—scutibranchiate; foot lobate and filamented along the side; shell nacreous within; operculum smooth and calcareous in Phasianella; orbicular, horny in Turbo, with a solid convex, calcareous, inner pagina, and a turbinate ventricose shell. Imperator has an oblong or ovate operculum, also calcareous within; in Adeorbis it is calcareous, multispiral. Rotella has a flat, polished shell; Delphinula a horny concentric operculum and a turbinated shell; Trochus a membranous operculum and a conical shell with a flat base. Gena is ear-shaped, inoperculate, and Broderipia is limpet-like. 5. Neritidæ—scutibranchiate; foot oblong, triangular, not fringed; shell thick; peritreme crescentic, spire not prominent; operculum calcareous, paucispiral, often articulate. Nerita is marine; Neritina freshwater;

* This genus has a rudimental operculigerous lobe.

Clithon is spiny; Navicella is patelloid, with a rudimental operculum.

§ IV. Ctenobranchiata—gills two, pectinate, in the mantle cavity; penis present; never rhipidoglossal. It is divided into two sub-sections, according as the peritreme is entire (Holostomata), or elongated into a canal corresponding to the siphon of the mantle (Siphonostomata).

Sub-section 1. Siphonostomata consists of three series:—I—Tænioglossata, including the following families:—1. Strombidæ—head with an annulated rostrum; eye-stalks thick, giving rise to the tentacles when they exist; outer lip of the shell wing-like; foot narrow, divided; outer edge of mantle entire (Strombus), or cleft (Pteroceras); spire long in Rostellaria. Terebellum has no tentacles, and unequal eye-stalks. 2. Aporrhaidæ—foot trigonal; eye-stalks small at the base of the long tentacles; outer lip of canal expanded; spire long (Aporrhais), or short (Struthiolaria). 3. Pediculariadæ—irregular shells, parasitic on Mediterranean corals; eyes sessile at outer side of the base of tentacles. 4. Doliidæ—siphons recurved; foot small, with lateral lobes; shell ventricose; eyes on short stalks; operculum none (Cassidaria, Dolium), or small (Cassis); shell usually thick or thin, spirally ribbed (Dolium), in Ficula pear-shaped, with a long canal. 5. Tritoniidæ—spiral elongated, with continuous (Ranella), or discontinuous (Tritonium), varices, and long siphonal canal; foot small; shell sometimes distorted (Persona). 6. Cypræidæ—shells porcellanous, smooth-ribbed (Trivia), or tubercled (Pustularia), involute; tentacles long, subulate; foot broad; operculum none; inner lip of shell corrugated, rarely smooth (Ovulum, Volva).

Series II. Toxiglossa—radula 1 . 0 . 1; siphon with a poison gland opening through the hollow teeth. Families 7:—Conidæ—foot with one conspicuous pore; shell inversely conical, with a long narrow aperture, with simple lips, and nearly flat (Conus), rarely produced spire (Dibaphus); proboscis and siphon short; operculum small, unguiculate. 8. Terebridæ—shell long, multispiral, acute; mouth and canal small; siphon long; operculum ovate, pointed, with apical nucleus. 9. Pleurotomidæ—shell fusiform or conical, its

outer border with (rarely without, Bela) an anterior notch; operculum lamellose or none (Mangilia). 10. Cancellariidæ—spiral, ovate shells; proboscis none; tentacles far apart, with basal eyes; operculum none; foot small, triangular.

Series III. Hamiglossata—(1-1-1). Families, 11. Muricidæ—shell with foliaceous or spiny varices, a straight canal; eyes at the bases of the tentacles; foot broad, single in front, with leaf-like operculum. Murex has at least three rows of varices; Typhis has hollow spines; Trophon a crown of lamellose varices; Fusus is spindle-shaped, with an oval mouth; Pyrula pear-shaped, with a wide opening; Columbella thick, with a narrow mouth; Fasciolaria has fusiform shells, whose outer lip is striped transversely. 12. Buccinidæ—anterior canal short; foot large; border of the outer lip smooth (Buccinum), or toothed (Nassa), often cancellated (Phos), or smooth, oval (Pusionella); canal sometimes reduced to a notch (Purpura). In Concholepas the mouth is very wide, and the spire almost none; Monoceros has a strong tooth on its outer lip; Magilus, living in coral, has, when young, a regular spiral shell, but becomes irregular as age advances. 13. Mitridæ—shell smooth, with a pointed spire, small mouth, and sharp columellar folds; proboscis long; operculum none or small. 14. Olividæ—foot large, trigonal, divided into fore and hind lobes; eyes medial, stalked; proboscis short; siphon long; shell cylindrical, smooth (Oliva, &c.), or longitudinally ribbed (Harpa). 15. Volutidæ—rachiglossal; shell notched anteriorly at peritreme; columella sharply folded; siphon long; proboscis short; operculum none; shell oval.

Sub-section 2. Holostomata — herbivorous, with no siphon, and an entire peritreme. This includes the following series;—I. Ptenoglossa (∞ . o ∞), including, 16. Scalariidæ—foot small; eyes near the base of the tentacles; operculum corneous, paucispiral; shell aciculate, white, longitudinally ribbed (Scalaria). 17. Solariidæ—shell trochiform, last whorl angular, widely umbilicated; mouth four-angled; eyes at the base of the lower groove-like hollow tentacles. 18. Ianthinidæ—shell thin, snail-like, bluish, with thin lips; eyes none; tentacles four; pelagic inoperculate forms, secreting a purple fluid; eggs cohering into a "raft."

Series II. Tænioglossata (3 . 1 . 3), including, 19. Cerithiidæ—foot small, round; eye near the base of the tentacle; shell multispiral, slender, without or with periostracum, with small mouth, canalated fore and aft; operculum horny, spiral. 20. Melaniadæ—freshwater; shell often corroded, slender, with a thick, dark periostracum; outer lip of peritreme sharp; tentacles arch-shaped; proboscis not retractile. 21. Pyramidellidæ—shell oval, or tapering, nucleus dexiotrope; tentacles broad, ear-shaped; proboscis retractile; operculum horny (Stylifer, Chemnitzia, &c.) 22. Turritellidæ—shell slender, tapering, multispiral; apex often broken; peritreme round, simple; gill single; foot short; operculum horny; Cæcum has a tubular, non-spiral shell, with a multispiral operculum. 23. Vermetidæ—sessile; shell irregularly spiral, tubular, frequently fissured (Siliquaria), one, left, pectinate gill. 24. Xenophorida—shell lamellose, trochiform, with many agglutinated foreign bodies in it; proboscis long; eyes at the base of the long thin tentacles (Phorus). 25. Naticidæ—shell globular, paucispiral, smooth, short-spired; mouth semilunar; columella swollen; proboscis long; eyes may be absent. 26. Entoconchidæ, including a curious parasite existing as a shell-less pouch attached to the calcareous ring of Synapta, only containing sexual organs; from these develop a naticoid shell, whose further history is unknown. 27. Marsenidæ—shell thin, ear-shaped, horny, inoperculate; hidden in the foot; the larval shell is completely shed. 28. Acmæadæ—shell and animal limpet-like; radula long; operculum none; foot large. 29. Capulidæ—foot as last; shell patelliform with a trace of a spire, and an internal, lamellar, horseshoe-shaped (Capulus, Calyptræa), or funnel-shaped (Crucibulum), or horizontal, muscular lamella (Crepidula); Hipponyx forms a shelly lamina under the foot. 30. Littorinidæ—foot thick; eyes at base of tentacles; operculum paucispiral, horny; mouth entire round; shell oval; siphon rudimental. 31. Paludinidæ—freshwater; shell oval, with olive-green periostracum, and entire mouth; operculum eccentric, lamellose. 32. Valvatidæ—freshwater; globular or discoidal, with a tentacle from the mantle; gills projecting out of the mantle cavity; foot small. 33. Ampul-

lariadæ—freshwater; foot large; eyes on short stalks; pulmonary cavity coexisting with the gills.

§ V. Neurobranchiata—terrestrial, diœcious, operculigerous, breathing air by a vascular net-work on the roof of the mantle cavity; tentacles two, non-retractile, behind or at the base of which are the eyes; penis anterior. This includes:—1. Cyclostomidæ—shell conical, tænioglossate, often depressed; foot long; mouth round or oval, entire or with a double margin; operculum paucispiral or multispiral, horny or calcareous. 2. Stoastomidæ—shell conical; columella flattened; eyes at the base of the tentacles; radula rhipidoglossal; operculum not spiral, but semicircular, triangular, or none. 3. Aciculidæ—foot small; lips parallel; peritreme thickened (Acicula), or canaliculated below (Geomelania).

Order 2. Pulmonata (*Cuvier*)—air breathing, symmetrical, terrestrial, herbivorous, hermaphrodite Gasteropods, naked, or shell-bearing, with no operculum, except in Amphibola. The lung is behind the heart, and the larva has no conspicuous velum. The shell is deposited not outside, but as calcareous granules, in the mantle substance. They are very abundant in warm climates. They are divisible into three sub-orders:—

1. Acera—with no tentacles, including the Australian family Amphibolidæ, living in brackish water; with the penis under the right eye; shell umbilicate, globular.

Sub-order 2. Stylommatophora—eyes on the ends of stalks or processes of the body wall (hinder tentacles), which may be contractile and coexisting with two other simple tentacles, as in Veronicella, or with no other tentacles, as in Onchidium; or the tentacles may be two; retractile, as in Janellidæ; or four retractile, as in the following families:—Limacidæ—shell hidden in the mantle (which is fused with the back); jaws strong, crescentic. Arion has a shell of several pieces and a caudal gland, as in Geomalacus, while Limax, the common slug, has no tail gland. Parmacella has a subspiral shell. 2. Testacellidæ—carnivorous, small; jaws none; the shell may include the whole body (Glandina), and may have its last axis oblique (Streptaxis); it is rarely conical, multispiral (Cylindrella), or small, as in Testacella and Dau-

debarda. 3. Helicidæ—herbivorous; shell external, spiral; body separated from the foot; jaws strong, crescentic. Helix, the snail, has a complete peritreme with separate borders, modified by the projection of the whorl before the last; its 1800 species form about fourteen sub-genera. Bulimus has oval shells, with unequal margins to the peritreme, and includes 1200 species. Achatina is Bulimoid, non-umbilicated, with an open posterior end and a sharp edge. Vitrina has a glass-like shell with a simple mouth. Nanina is snail-like, polished, umbilicated, depressed, with a bilobed mantle. Zonites is umbilicated, multispiral, with a tail gland. Achatinella is often dexiotrope, like the slender cylindrical Clausilia. Pupa is ovate or cylindrical, with a toothed or plane peritreme, and with tentacles, small, anterior, or none (Vertigo).

Sub-order 3. Basommatophora—eyes posterior, or internal to the two tentacles, sessile, including:—1. Limnæidæ—shell horny, translucent, with a large body whorl, a sharp lip, often retroverted (Anphipeplea), rarely dexiotrope (Physa), discoidal (Planorbis), or patelliform (Ancylus), or neritiniform, with a wide mouth (Latia). 2. Auriculidæ—shell thick, with a thick periostracum; inner lip folded; jaws strong; the spine may be much elevated (Carychium), the outer lip sharp or thick. Allied to this is the patelliform genus Siphonaria, which has a gill in the pulmonary cavity, and is thus a passage form. Pulmonates have been arranged according to their jaws, by *Mörch*, into six groups:—1. Oxygnatha, or those with a sharp tooth on the jaw, as Limacidæ and Vitrinidæ. 2. Agnatha—jawless, as Testacellidæ and Onchidiidæ. 3. Aulacognatha—with striped jaws, crenated at the edge, as Pupa, Clausilia. 4. Odontognatha—jaws with marginal rows of teeth, as Arionidæ, Helicidæ (except Pupa, &c.) 5. Goniognatha—with superficially striated jaws, as Orthalicidæ, Veronicellidæ, Janellidæ, Succineidæ. 6. Polygnatha—with more than two jaws, as Limnæidæ.

CHAPTER XXXVIII.

CLASS 3.—CEPHALOPODA.

MARINE, carnivorous, diœcious, symmetrical molluscs, the highest of the sub-kingdom; with partially cleft ova; a distinct head surrounded by the modified foot; respiration branchial; sense-organs well developed; the bodies are antero-posteriorly shortened and vertically elongated; they creep with the head downwards, and swim laterally with their upper side forwards.

The integument is smooth, rarely papillose, covered by a porous cuticle of united cylinder (Nautilus) or pavement cells, on a basis of fibrillar tissue, beneath which are one or two layers* of nucleated pigment cells with contractile processes (chromatophores). The pigment is rarely in the surface epithelium.† Under these is often a layer of lamellar, highly refracting corpuscles (*flitterchen*‡) producing by interference a play of colours.

Beneath these layers, loose connective tissue covers a muscular and connective substratum, containing usually a network of capillary blood-vessels. The integument of the sides of the body is differentiated into a mantle which incloses a cavity whose opening is directed downwards (backwards in progression), and which lies on the posterior (or what is generally con-

* When of two layers they are of different colours.

† As in the tentacles and about the eyes of Nautilus; some of those cells are ciliated.

‡ The chamæleon-like change of colour, so striking in Cephalopods, is due both to the changes in shape and size of the chromatophores and to these *flitterchen*.

sidered as the ventral) surface. The inferior free mantle edge may completely surround the head as a collar (Sepia), or may unite with the body integument antero-laterally, so that the mantle becomes only a latero-posterior duplicature of skin dorsally (posteriorly). The lateral integument is often expanded into flat lobes or fins, which may be rounded (Sepiola) or angular (Ommastrephes), terminal or sub-terminal.

The mantle may secrete no shell (Octopus), or may have imbedded in it a pair of thin conchiolin plates anteriorly (Cirrhoteuthis). In Loligo there is an anterior shell (*gladius*) of conchiolin, inclosed in the mantle, consisting of a central rachis, without (Sepiola) or with two thin lateral wings,* varying in shape. This is formed within a "pen-sac," which is a space formed in the embryo by an upgrowth of a ring-like wall of the mantle, the margins of which close together by later growth. In Octopus the fossa is developed, but its margins never close in. In Sepia there is posteriorly, and united to the horny "pen," a lamellated, soft, calcareous shell, forming the well-known cuttlefish bone (used for tooth powder), each of whose lamellæ is separated by an interspace filled by animal matter.

The extinct Belosepia had a similar shell, but the lamellæ were farther apart, separated by hollow intervals. In the extinct Belemnites the interior (*phragmocone*) is composed of lamellæ, separated by chambers which communicate with each other by a canal (*siphuncle*), outside which a part of the original lamellose sepiiform shell remains as a coating (*pro-ostracum*), covered with a horny sheath, and like the shell of Sepia, often ending in a beak or rostrum. The belemnitic

* These wings are broader in the female than in the male.

internal shell is usually straight, but in the miocene Spirulirostra is coiled, conducting us to the form of shell in the existing Spirula, where the chambered, coiled, purely nacreous internal shell represents the phragmocone of a belemnite. We know as yet of no passage forms linking these to the external shells of the same pattern, like Nautilus, but such may have existed among the numerous fossil forms (Crioceras, &c.) of whose soft parts we know nothing. Many consider these two kinds of shells as utterly diverse in morphological nature.

There are two types of external shells among Cephalopods—1st, the camerated form, in which the animal inhabits a large terminal compartment, behind which are several air-holding* chambers, divided by transverse septa, but communicating by a tubular prolongation of the body cavity (siphuncle). Some fossil forms are straight (Orthoceras), curved, hook-like (Hamites), openly coiled (Crioceras), or involute (Goniatites, &c.), sometimes helicoid or turreted, and the septa dividing the chambers may be evenly concave towards the peritreme, or complexly lobed at their margin of attachment (Ammonites, &c.) The siphon may be columellar, median, or lateral. The shell consists of an outer porcellanous, an inner nacreous, and sometimes an imperfect middle, granular, coloured lamina. The second form of shell is unicameral, smooth, as in the female Argonauta, secreted by the lobed dorsal arms, and forming a parabolic spiral of 1⅝th whorls. It is to be regarded as a pedal shell, and its homologies are rather with an operculum than with a shell proper.

An internal skeleton exists in all as a cartilaginous

* This air contains more nitrogen than ordinary air, and no carbonic acid.

peripharyngeal crescent or ring, analogous, but not homologous to a cranium. In Nautilus it is horse-shoe-shaped, and its cornua end above and below in pointed processes. In Dibranchs it is median, peri-œsophageal,* with two lateral processes, either flat expansions forming roofs for the orbits, or else forming perfect orbital cavities. In Sepia there is also a pointed median cartilage outside the basal part of the arms, and also a semilunar piece in the anterior dorsal region of the mantle. In Octopus the latter is represented by two lateral pieces, with no medial part, and in Loligo it is absent. There is often a neck cartilage, largest in Loligo, absent in Sepiola; and at the base of the funnel are two hinge cartilages (absent in Octopoda). Along the sides of the lateral fins are two cartilages, long and sword-like in Sepia. The cartilage cells in Sepia send numerous long fine processes through the intercellular substance, giving it a finely striped appearance.

On account of the antero-posterior shortening of the body, the foot approximates to, and surrounds the mouth, and has its margin divided either into a cluster of many tentacles (Nautilus), or into 8–10 long sucker-bearing arms. Two epipodial lamellæ spring from the posterior side near the head, and, in most, unite to form a tube (*funnel*) directed downwards and backwards, with its upper end towards the mantle cavity. The mantle margin overlies it so closely in life that this funnel is the only communication of the mantle cavity with the outer world. The tentacles in Nautilus are triangular in section, and arranged in two circlets,

* Forming a hollow ring with the nervous system in its transverse cavity.

the outer wreath being incomplete over the funnel, and consisting of nineteen at each side, the two dorsal of which unite to form a *cucullus*, which, when the animal is retracted, acts as an operculum. The inner, smaller circlet consists of twelve tentacles on each side. Each of these tentacles has a basal sheath, and in the male the sheaths of the four ventral inner tentacles unite to form a spadix.* The female Nautilus has ninety-six tentacles.† The genus has a double musculus columellaris from the shell to the head cartilage, not continued into the tentacles.

The other Cephalopods have eight arms in a circlet round the head, formed of the modified margin of the foot, and two longer tentacular arms arising within these. These arms may be united by membrane to their tip (Cirrhoteuthis), or only at their bases; they are numbered from their dorsal side as first, second, third, and fourth pair.

Each arm consists of a central canal, containing an artery, a vein, and a nerve. Circular and longitudinal fibres surround this, and a dermal layer over all. Its oral surface is covered with rows of cup-like suckers, each of which has a smooth or toothed, hard epidermal ring round its mouth. Radial and papilla-forming vertical piston-fibres, by retracting the centre, help it to act as a sucker or adhesive organ; sometimes (Onychoteuthis) some suckers are modified into hooks. The *m. columellaris* in these is represented by a muscle extending from the head-cartilage. There are also in all Cephalopods—1, *m. collaris*, a broad band around the neck; 2, *depressor infundibuli;* and 3, *adductor infundibuli*, to alter the position of the funnel; 4, *m. lateralis* (under the ganglion stellatum in ordinary cuttlefishes), passing from the

* Somewhat similar to the hectocotylized arm of a Dibranch.

† 38 external, 24 internal, 14–15 pair of labial ten-tacles, and 2 pair of tentacles behind the eye. The male has 66.

head-cartilage to the side of the mantle. The fin along the side is moved by muscles attached to its cartilaginous support.

The mouth is surrounded by an annular lip, attached to the base of the arms by a buccal membrane. Within this is a parrot-like beak of two dark brown, vertical, conchiolin jaws, of which the under overlaps the upper. Internal to these is a soft ciliated (taste ?) organ, in front of the vertical internal tongue, on which is stretched the broad radula, armed with long hollow lateral hooks, with a dental formula in each row of 3–1–3, or (Eledone and Octopus) 4–1–4, or (Nautilus) 4–5–4. Into the mouth open one or two (Onychoteuthis, Eledone, Octopus) pair of large, smooth, or lobed salivary glands. The posterior pair is absent in Sepia, Loligo, &c.; short and small in Octopus and Eledone. In Nautilus there is a lateral (salivary ?) glandular mass on each side of the mantle.

The œsophagus is narrow and long, dilating into a fusiform crop in Nautilus. Argonauta has a long oval crop, but in Octopodidæ it is much shorter. In Nautilus the œsophagus passes through a transverse intermetameric septum, stretching between the head segment (prosoma) and the visceral bag (metasoma). The stomach is saccular, thick-walled (Octopus and Nautilus*), ciliated within; the cardiac and pyloric openings are close together, and the lowest part of the stomach is saccular. The intestine begins with a dilatation which in Nautilus is lamellar, in Loligo is spiral, in Rossia is curved and round; into this open the two bile ducts. The longitudinally folded intestine is moderately straight, and ends in the

* In this animal having tendinous plates and thick cuticle, like a bird's gizzard.

middle line of the mantle cavity, usually communicating with the funnel in an anus either round (Nautilus), or with one, two, three, or (in Sepia) four triangular anal valves; largest in Sepioteuthis; thread-like in Loligopsis; the flexure of the intestine is neural.

The liver is reddish yellow, witn four loose lobes in Nautilus; two separate (Sepia), or transversely united (Rossia) lobes; firm and compact in others. Yellow, firm lobules (pancreatic lobes), which communicate with the two bile ducts, are easily distinguished in most forms.

All but Nautilus have an ink bag, a long sac with a lamellar iridescent lining, and a slender duct opening near or into the anus (Decapoda). In Octopus it is imbedded in the liver; in Sepiola it becomes periodically enlarged, and divided into one central and two lateral parts, which show regular contractions. The secretion of this bag is *sepia*, composed of melanin, magnesic and calcic carbonates, and mucus. These animals hide themselves, when pursued, by darkening the water with this fluid. This sac is developed as a diverticulum from the chamber of the anal tubercle, and this is primarily a segmentation from the alimentary canal. In Cephalopods the systemic heart lies at the floor of the visceral cavity, and consists of a round or transversely oval ventricle, with striped muscles in its walls. It has a valve at each of its auricular and arterial openings. There are two auricles (four in Nautilus, Fig. 31, B). There are two aortæ, arising one at each end of the heart (Sepia, Loligo, Fig. 31, C), or close together (Octopoda, Fig 31, D). The cephalic aorta is the largest, and gives off pallial,

intestinal, and infundibular branches, and in the head ophthalmic and tentacular vessels, which may be united by an annular vessel round the mouth. The visceral aorta supplies the liver and genital organs, and in Ommastrephes gives off a pair of branches to the fins (pinnal), which are dilated into accessory circulatory organs. The arteries end in capillaries and laminæ which open into the veins, which vary in almost every genus. The brachial veins form a circular sinus at the base of the arms, and send a cephalic vein upwards, which receives pallial and visceral veins, and branches from the large lacunæ; it then divides into two (Dibranchiata) or four (Tetrabranchiata) branches, which go to the two or four gills. In Dibranchs these are dilated at the bases of the gills, and surrounded by muscular fibres, forming a pair of branchial hearts. The gills are pyramidal, non-ciliated, in the mantle cavity, and consist of united lamellæ or of complexly folded dermis, bathed by sea-water, which passes in and out of the mantle chamber in swimming.

The branchial veins from these dilate, and form the two or four auricles of the heart. The blood is colourless, and contains copper. On the branches of the cephalic vein, before they form the branchial hearts, there are spongy renal appendages containing cæca and often yellow or violet concretions projecting into the aquiferous lateral sacs of the mantle cavity, and communicating with the pericardium. These may be the homologues of the organs of *Bojanus* or of the gasteropod kidney, the spongy venous processes resembling the spongy glandular part of that organ, or they may be kidneys of another type. Over the surface are certain aquiferous pores, by which water enters the lacunæ and mixes with the blood; these may be cephalic (or a pair on the back of the head), as in Philonexis, Tremoctopus, Argonauta, or

buccal, four (Histioteuthis, Ommastrephes), or six (Sepia, Loligo), or anal (one pair at the base of the funnel), as in Philonexis, Ommastrephes, and Onychoteuthis; sometimes there are brachial pores at the base of the arms. Water also enters the perivisceral cavity, which here, as in other molluscs, acts as a large circulatory lacuna.

The cerebral, pedal, and visceral pairs of ganglia are close together, united by short commissures, or even coalescent. The pharyngeal ring is protected partly by the cartilage, and its investment is completed by a membranous sheath.*

The pedal ganglia in Nautilus give off branches which form a tentacular ganglion. In Dibranchs the corresponding nerves often unite into a common trunk. On each side of the mantle cavity on the *musculus lateralis* is a large *ganglion stellatum* connected with the visceral ganglion by commissures, and distributing branches to the mantle. From the cerebral ganglion arises a commissural band, which forms above the œsophagus an upper buccal ganglion, and ventrally below an inferior buccal, to which the sympathetic nerves are attached, two long stems running along the œsophagus, and forming a stomach ganglion, or pair of ganglia, giving branches to the other viscera. Two stems attached to the hypopharyngeal ganglion pass along the large venous trunks, and unite in a pair of branchial ganglia at the base of the gills, joined by a commissure.

The sense of touch is seated chiefly in the tentacles, taste in the before described pre-lingual papilla (or in similar organs in Nautilus). The organ of smell may be a short, trigonal, ciliated, hollow process, like the sheath of a tentacle (Nautilus) placed below the eye,

* This sheath is more complete in Dibranchs, in which the nerves often pierce through the cartilage to their destination. The intravaginal space is not filled by the nerve centres, but contains a fluid or a glandular (?) mass.

or a pair of ciliated grooves, one behind each eye, supplied by a nerve arising along with the optic (this organ is smaller in Octopods than in Decapods). Another peculiar sense-organ lies on the inner wall of the funnel, as a flat, whitish eminence whose surface consists of cells containing strongly refracting, rod-like bodies. The organ of hearing is a round sac, in Tetrabranchs lying on, in Dibranchs inclosed in, the head cartilage, and containing one or many (Nautilus) flat or rounded otoliths; its nerve springs from the pedal ganglion. There is a membranous sac or labyrinth within the cartilage, separated from it in Octopods, but joined to it by processes and sulci, which renders it complex in Decapods. The nerves end in fine rods, or under a thick epithelial "auditory" plate. A ciliated canal traverses the cartilage, whereby the dermal sac has been involuted for the formation of the otocyst. The optic nerve arises from the brain, and forms a large ganglion directly behind the large eye-ball, whose orbit of cartilage is continuous into the sclerotic. Below and behind the eye-ball is a peculiar "white body,"* probably an aborted nerve ganglion, representing the epipharyngeal ganglion of other molluscs. The anterior wall is transparent, and forms a cornea in Loliginidæ.

Investing the eyeball is a silvery lamina (*argentea externa*), under which is a somewhat cup-like cartilage forming the fundus of the eyeball, and pierced by the branches of the optic ganglion. The thick front edge of this cartilage is called the equatorial ring, and from it longitudinal muscular

* In development the optic ganglion grows at the expense of the white body, and, according to the researches of *Mr. Lankester*, the optic nerve and ganglia appear to be developed from the mesoblast.

fibres pass forwards (fibres of *Langer*) to the origin of the iris, which is a circular fold in front of the lens, also containing a support-cartilage within it. Within this is an *argentea interna*, and the retina. The front of the choroid is thickened into a *corpus ciliare* (*c. epitheliale*), developed from the anterior lining cells of the primitive optic vesicle, which surrounds equatorially, and is continuous with, the biconvex lens whose hinder surface is the more convex. Behind the lens is a fluid vitreous humour. The retina consists of two layers, an outer (*stratum conjunctivum*) and an inner (*s. epitheliale*). These consist of seven lamina, the outer of four* and the inner of three.† There is neither lens nor cornea in Nautilus, and the eye chamber is an open cup, as it is in the earliest stage in the embryo of Dibranchs. There is no cornea in Loligopsis nor Histioteuthis, and in Loligo there is a hole in the cornea, whereby the sea-water bathes the front of the lens.

The lobate, unsymmetrical ovary dehisces into a segment of the perivisceral space, from whence its products enter the usually azygous genital ducts (paired in Octopodidæ, Ommastrephes). The oviduct opens at the beginning of the funnel, or in forms with hectocotylized males, deeper in the mantle cavity. The oviduct wall has an annular gland in Nautilus and Octopods, and near its mouth a pair of rudimental glands, long lamellar pouches, secrete the sheath for its eggs.

The testis has a capsule which, like that of the ovary, is only attached to it at one spot; its vas deferens is long, coiled, widening to its end, often with one or two prostatic appendages, or a coiled cæcal pouch. The papillary opening of the vas has

* Membrana limitans, or surface connective, nerve vesicles, and a reticular or connective support layer.

† A pigment layer containing rods, granules, a layer of rods and an inner limiting homogeneous layer.

sometimes a long surface groove communicating therewith. Sometimes one arm, with few suckers (Sepia), or with a spoon-shaped end (Octopus, Eledone), is set apart as a male sex-organ, and reaches a large size, having a filamentary extremity and a Needhamian vesicle at its free end; this, being set free, enters the mantle cavity of the female, and thus impregnates it. This arm is called a *Hectocotylus ;* it is the third right arm in Octopus Carena, and Tremoctopis, the third left in Argonauta, and was formerly regarded as a trematode parasite. A new arm is produced when the hectocotylus is detached. In Nautilus the oviduct opens unsymmetrically on the right. The spermatozoa are united by the secretion of the cæcal pouch into cylindrical spermaphores, the moving filaments of *Needham.*

The ova undergo only very partial segmentation at a germinal flat disc at the pointed end of the ovum; here a cap of cells becomes visible (*klastoplasts*), and in the underlying substance a series of bodies form, which look like nuclei, but without differentiated cell areas round them (*autoplasts*); these become branching contractile cells, in which inheres the rhythmically contractile power of the yelk sac.

After segmentation, the mantle, gills, and epipodia form, then the sense-organs, then the foot and its marginal processes.* There is no metamorphosis, and the organs are formed by the time the shell breaks.

Of the 2000 known species, only 218 are now living. They are divided into two orders:—

1. Tetrabranchiata (*Owen*)—shell siphonate, camerated;

* Most of our knowledge of the embryogeny of Cephalopods we owe to *Mr. Lankester*'s researches, and to those of *Salensky*.

gills four; tentacles numerous; ink-bag none; epipodial lamellæ convolute with ununited edges; eyes stalked; mantle attached annularly to the shell. There is one living genus, Nautilus, the type of the family Nautilidæ, whose septa are simply curved; of the fossil genera, ten belong to the same family, and eighteen to the family Ammonitidæ, with lobate septal margins.

2. Dibranchiata (*Owen*)—external shell none; arms 8–10, acetabuliferous; epipodia united to form a funnel; epidermis with chromatophores; an ink-bag, and two gills with branchial heart at base, also exist. About 212 species are living, 159 being extinct. They are divided into two sub-orders:—1. Decapoda (*Leach*)—with two tentacular arms, except in Cheiroteuthis, retractile into pouches under the eyes, and pedicellate suckers. Here are included two series:—I. Chalcophora—with an inner calcareous shell. This includes the following families:—Spirulidæ—shell an open spiral, camerated, siphonate, nacreous, included in the hinder part of the body; eye with a closed cornea. Belemnitidæ—extinct, with a straight included, camerated, siphonate shell; arms with six rows of small suckers. Sepiadæ—oval, with long, lateral fins; eyes with closed corneæ; shell prolonged to a point; its lamellæ not separated by siphonate chambers (Cuttlefishes). Series II. Chondrophora—shell of conchiolin supported either by two internal fleshy bands (Cranchiadæ, Loligopsidæ), or by three internal cartilages (Cheiroteuthidæ, Onychoteuthidæ, Loliginidæ). Herein are contained two groups:—1. Myopsidæ—eyes with closed cornea; littoral, including the families Loliginidæ—elongate, with suckers on the buccal membrane, and inner shell as long as the body; mantle free. Sepiolidæ—short, with rounded fins, and no buccal suckers; mantle attached anteriorly; shell half as long as the back. Group 2. Oigopsidæ—eyes with open corneæ, pelagic; including Cranchiadæ—round, with terminal fins; mantle united to the small head by a neck band; eyes large, and the corneal opening small; funnel with a valve. Loligopsidæ—soft, transparent, long, pointed behind, with terminal fins; funnel long, with no valve; eyes stalked; shell lancet-shaped, as long as the back. Cheiroteuthidæ—long, with two dorsally

placed fins; mantle united by hinge cartilages, linear or dilated, not by muscle; arms united by membrane; funnel short, with no valve; shell long, slender; tentacles non-retractile. Thysanoteuthidæ—long or oval; arms free; inner shell auricled at base, or hastate. Onychoteuthidæ—long, cylindrical; eyes with a wide corneal opening and a sinus above; arms with hooks along their margin; funnel with a valve; shell dilated at both ends (Enoploteuthis), in front with one central and two lateral ribs (Ommastrephes). Sub-order 2. Octopoda (*Leach*)—arms eight, with sessile suckers, each without a cuticular ring; body short, roundish; mantle usually without a hinge cartilage; oviduct paired; nidamental gland none. This includes Cirrhoteuthidæ—arms united by membrane to tip: body soft, with round fins; a cartilaginous inner shell; the suckers alternate with cirrhi. Octopodidæ—mantle joined to the visceral sac by a broad muscle at the median line; shell and water pores none; suckers short, in one (Eledone) or two rows (Octopus). 13. Philonexidæ—mantle with a cartilaginous, button-like hinge apparatus, and many water pores; suckers fleshy, peduncled; arms all free (Philonexis), or two of them webbed (Tremoctopus). Argonautidæ—arms subulate, the two upper webbed at end, and secreting a shell in the female; mantle hinge apparatus as in last; male much smaller than female.

The gigantic pelagic forms, krakens of the Scandinavians, belong to Onychoteuthidæ, and form the genus Architeuthis of *Steenstrup*. The arm of one of these, driven on the west coast of Ireland in 1875, measured thirty feet in length.

CHAPTER XXXIX.

SUB-KINGDOM 6.—ARTHROPODA (*v. Siebold*).

SYMMETRICAL, mostly diœcious,* non-ciliated schizocœlous (p. 47) personæ, of a limited† specifically constant number of often heteronomous metameres or *somites*, each usually with a pair of ventrally-articulated,‡ hollow,§ jointed organs, as feelers, jaws, or limbs. The body consists of head, thorax, and abdomen: the first contains not fewer than four united somites, bearing the sense-organs preorally; the second bears the locomotory limbs; the third contains the vegetative and reproductive organs.‖ The heart, when present, is dorsal, tubular, often segmented, and the circulation is more or less lacunary. Breathing takes place by the surface, gills, or tracheæ. The digestive system is absent in some parasitic Crustaceans, aproctous in the larvæ of Myrmeleo and some Hymenoptera. In others the mouth is anterior, ventral, the anus rarely dorsal (Dias, &c.), usually terminal, or sub-terminal. The intestine is seldom tortuous (Insecta), or it may have lateral cæca (Arachnida). On the surface is a firm, coloured, lamellated, nearly structureless layer of Chitin,¶ with or without an in-

* Except Cirripedes and Tardigrades, and anomalously in some insects.

† Except in Myriapods.

‡ The wings of insects and the shell-flaps of Entomostraca are unjointed processes, not true limbs.

§ Containing muscles for their motion.

‖ These organs are never metamerically multiplied, though the respiratory and nervous systems are so arranged.

¶ *Peligot* supposes that Chitin ($C_{17}H_{14}NO_{11}$) is a mixture of a proteid and a cellulose compound.

terstitial calcareous deposit, pierced by many pore canals* and by processes of the dermis, strong around each metamere, thin in each intermetameric space, so as to allow of motion, and it is periodically shed and renewed. It is often prolonged for a short way, or for the whole length, into the interior of the digestive canal, and sometimes projects into the body for the attachment of muscles (endophragma, or endothorax). Uni- or multicellular hairs or bristles may form as extensions of this layer, either firmly attached or loose (scales of Lepidoptera). Under this is a colourless, chitinogenic, cuticular layer of hexagonal epithelial cells, or of continuous protoplasm, with regularly scattered nuclei. Beneath this is the connective dermis. The muscles are colourless, not in laminæ, but metamerically divided, with transversely-striped fibres grouped in numerous bundles.† There is a pharyngeal nerve ring, with an epipharyngeal brain-ganglion (absent in Pentastomidæ),‡ and a hypopharyngeal pair of ganglia with complex commissures,§ from which a double ventral cord extends, having in each metamere a pair of ganglia whose upper surfaces are motor and the lower sensory (?).

* Which are either fine, and full of air and water, or larger, and containing protoplastic processes of the cuticle. In Sphæroma they are wide, anastomosing, and branching.

† Lubbock describes fifty-eight in a single somite of an insect, arranged as flexors, extensors, elevators, depressors, retractors, protractors, adductors, abductors, and rotators. The fibres do not anastomose, and are of great power—thus a flea can leap 200 times its own height.

‡ Not homologous with the brain of a Vertebrate; nothing but the most general comparisons can be made between the nerve centres of a Vertebrate and those of an Arthropod.

§ Complex, because the head ganglia are made up of several fused metameric ganglia.

The nerve cells are unipolar, and the interior of the ganglion consists mostly of granular substance: many have a sympathetic system having its roots in the ventral ganglia, and a separate vagus nerve attached to the pharyngeal ring. The ova undergo partial cleavage,* the undivided part of the yelk remaining within the elongated blastoderm, which early shows a primitive streak and a division into symmetrical lateral swellings. Except in Isopods and Amphipods the segments appear before their appendages. The germ divides into two layers, the outer forming the skin, muscles, and heart, the inner, the digestive and reproductive (?) organs. Parthenogenesis occurs in several cases, Metagenesis † in one. In most cases the young undergo either progressive or retrogressive metamorphosis.

There are two primary divisions of Arthropoda :—

Division I. Branchiopnoa (*Schmarda*)—water-breathers,‡ mostly with two pairs of jointed head appendages or antennæ. This includes the polymorphic class Crustacea (*Latreille*), characterised by having the body divided into cephalo-thorax,§ abdomen, and often post-abdomen. Each metamere usually bears an appendage, even when it is fused with its neighbours. The "crust" of each metamere consists of a dorsal and a ventral lamina united at the point of attachment of the limbs. In some the dorsal shell consists of two median, *tergal*, and two lateral, *epime-*

* Except in some Cirripedia, Copepoda, Pentastomidæ, the summer eggs of Daphnia, Artemia, &c.

† Heteropeza, Family Cecidomyidæ.

‡ Some Isopods are terrestrial, but gill-bearing.

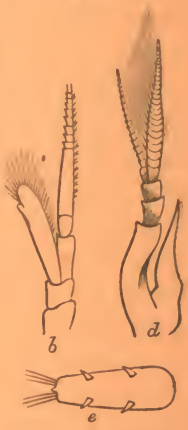
§ Sometimes only the anterior thoracic segment or segments unite with the head, leaving the hinder free.

ral, pieces, while the ventral consists of two central sternal and two episternal portions. These plates are always united, and at their sutures send in apodemata or processes. In lower forms the number of somites is varied by suppression or multiplication (Apus). The normal number of post-abdominal somites is six, of abdominal, five, of thoracic, three, and of cephalic, six.

The chitinous layers are usually calcified; the cuticle* often contains unicellular glands opening into the pore canals, sometimes clustered (Argulus), and stellate pigment cells, green, purple and red—the latter colour being the most permanent, as boiling or reagents redden the others.

The limbs vary in each class, but in the higher forms the arrangement is as follows:—Pre-orally there are two pair of antennæ, the anterior smaller (antennules), and the hinder larger: the former usually consist of three basal joints (the basi-, ischio-, and meropodite), terminated by a many-jointed annulated feeler or pair of feelers: the latter has five basal joints (coxo-, basi-, ischio-, mero-, and carpopodite), and a long, ringed, feeler, like the foregoing. The sternum of the antennary somite is called *epistoma*, and behind it is the *clypeus*, *labium*, or upper lip. The post-antennar segment bears as its appendages on each

Fig. 34.



Hippolyte Gordoniana; *b*, external antenna; *d*, inner antenna; *e*, telson.

* In Sapphirina the cuticle is marked on its surface by a system of wavy lines which give it an irridescent appearance.

side a mandible, which, with its fellow of the opposite side, forms the front pair of jaws; each usually bears externally a several-jointed palp, only absent in terrestrial and parasitic forms; the next segments bear maxillæ or hinder jaws, and one or more of the

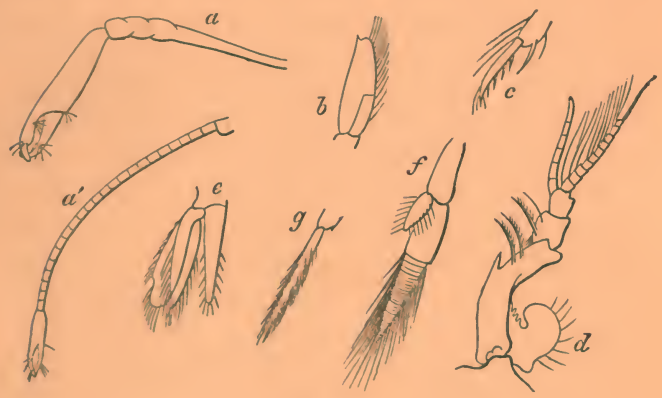


Fig. 35.

Limbs of Pandalus Jeffreysii :—*a*, *a'*, right and left 2nd pair of pereiopoda; *b*, outer antenna; *d*, inner antenna; *c*, 3rd pereiopod; *e*, telson; *f*, pleopod; *g*, gnathopod.

following or thoracic appendages are also specialized for the purpose of chewing.

The limbs behind this in lower forms consist of a basal process (*proto-podite*), to which is appended an outer (*exo-podite*), and an inner (*endo-podite*) process, the latter sometimes represented by tufts of bristles: in the higher forms the protopodite is lengthened, and divided into parts corresponding to those in the base of the antenna above given, and terminated by two joints representing the ringed end of the antenna (*pro-* and *dactylo-podite*).

The mouth is ventral, often displaced a little back-

wards.* It has, above, the labium, and below, a lower lip (in Isopods and Amphipods), or a bifid tongue laterally lie the masticatory limbs and their approximator and divaricator muscles. The salivary glands are absent or unicellular in Copepoda and Cladocera; largest in Gyge. The narrow œsophagus dilates into a crop in some Entomostraca, and ends by projecting into the stomach, whose anterior part is generally gizzard-like, muscular, and lined by chitinous tooth-processes, shed at each moult. The deepest portion of the chitinous teeth is calcified in Decapoda, forming a solid mass (Crab's eyes), pierced by pore-canals. The posterior part, or chyle-stomach, is thin-walled, and usually constitutes the longest part of the digestive tract; it may be of equal calibre throughout, or dilated anteriorly, as in Isopods. Into it opens the liver, which may be either simple cæcal pouches or as a complex gland. The cæca may be one azygos (Schizopoda, Sida, Pleuromma); two, short (Cladocera), or long (Caprella, Cyamus); two lateral and a medial (Polyphemus, Temora); two pair (Oniscus, Gammarus, Lygidium); three pair (Idothea, Arga, Ligia); four pair (Mysis, two small anterior and two large posterior, Balanus), or none (Chthamalus, Coronula, &c.) Or the cæca may be divided at their fundus, or ramified (Argulus, Hedessa). In Apus there are seven, ending in branched glandular nerves. In Phyllosoma there is a pair of finely-branched cæca. The second form of liver consists of numerous follicles scattered over the wall of the chyle-stomach (Bopyrus

* Sometimes so much so that the œsophagus first bends forwards, and then turns sharply on itself as in Limulus.

and Stomapoda).* The hepatic cells are yellow or brown, and contain oil globules. Similarly colored cells may form patches on the wall of the chyle-stomach. The intestine is short, straight (except in Cladocera), sometimes sacculated (Sapphirina), and possessing cæca; rarely villous in patches (Gyge), or marked on its inner wall with longitudinal grooves (Isopoda). The anus is terminal, ventral, except in Cladocera and some Copepods. In Astacus, Limnadia, Daphnia, &c., the intestine has been observed to take in and discharge water rhythmically. Where the chyle-stomach joins the intestine, or in the intestine, are often cells holding concretions (of uric acid?) forming a layer of limited extent. In some larvæ this renal area is isolated in a special cæcum, which persists in Cyclopsine Castor.

The other secretory glands are:—1. A poison gland in Argulus, seated beside the mouth, with its duct opening on the proboscis. 2. The shell gland of Copepoda, a coiled, fine tube on each side of the head, opening by a slender duct at the base of the antenna. In Phyllopods its duct opens into the mantle cavity. In Schizopods and Decapods it is seated in the basal joint of the antenna, and hence is called the antennary gland, or the green pregastric gland, from its colour in the crayfish. 3. The cement gland in Cirripedia, placed at the base of the pedicles (which its duct traverses); its secretion, poured out at the fixed end of the stalk, is the medium of attachment. In the Balanidæ this gland is complex, and lies on the basal plate of the shell, which is surrounded by the anasto-

* There may be ten hepatic lobes, as in Stomapoda. In Decapods they are combined into a bi-lobed organ.

moses of its ducts. This and the preceding gland may be homologous, and possibly the "*roots*" of Rhizocephala may represent its ducts.

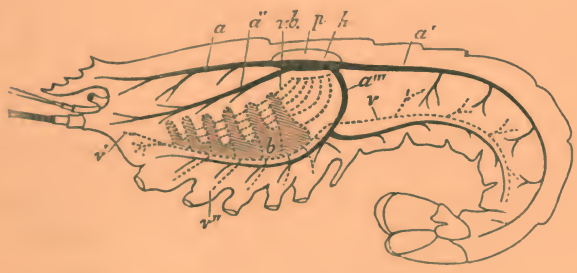
Beside the intestine in the abdomen is a mass of connective tissue and undifferentiated protoplasm, containing yellowish or reddish fat: these are largest proportionally in Entomostraca, and are among the chief sources of the oil which many fishes store in their livers. In Copepods this adipose body has a lacunary structure, and may act as a mesentery. Digestive organs are absent in the rudimental males of Cirripedes and parasitic Copepoda. The intestine is absent in Monstrilla.

The body cavity contains blood, which is colorless, reddish, or pale violet, with nucleated white corpuscles. A heart exists (except in Cyclopidæ, Corycæidæ, Harpactidæ, and Peltididæ, among Copepoda, most Ostracodes, and a few others) as a dorsal vessel, whose simplest form, as in Cladocera, is a sac, over the intestine, receiving blood by two lateral openings (*venous ostia*), and sending it forward by one short stem to bathe the brain, and enter the interstices of the tissues, from whence it is returned to the heart.

In Pontellidæ and Calanidæ there is a posterior ostium as well as two lateral; and in Calanella the aorta is longer, and divides into two. In Argulus there is one ventral osculum, and the blood is sent by the heart partly through the body and partly through a medio-posterior opening to the gill-like appendages. In Phyllopoda the heart is elongated, and composed of successive chambers (twelve in Apus), like a chain of communicating Daphnia hearts. These have many ostia (twenty pair in Artemia), but they do not correspond to the metameres, as there is usually one for several somites. In Poecilopoda the heart is surrounded by a pericardiac sinus;

in Limulus it has seven pair of ostia, and sends not only an arterial stem fore and aft, but also four branches from four of its intermediate chambers: these divide in the abundant interstitial tissue, and end in lacunæ. In Isopoda there are fewer ostia (three in Tanais), and the heart stretches forward to near the head. It extends towards the tail in Amphipoda, where the ostia are also few (three, Phronima, seven, Gammarus). These have one anterior aorta, or an anterior and a rudimental posterior. In the larvæ of the Podophthalms there are two venous ostia; but as development proceeds, the number of chambers (five) and ostia may enlarge, as in Stomapoda, and the heart then gives off anterior, posterior, and lateral

Fig. 36.



Circulatory system of Lobster; *p*, pericardium; *h*, heart; *a*, middle anterior aorta; *a''*, hepatic artery; *a'''*, ventral artery; *a'*, posterior aorta; *v*, ventral venous sinus; *v'*, veins from head; *v''*, veins from the limbs; *b*, gills; *v.b*, branchial veins.

branches, or as in Schizopoda and Decapoda the organ becomes concentrated, reticulated within, not divided into chambers, and with its five pair of ostia not in a series, but in a group. The anterior aorta is short, and gives off three branches, a middle to the brain and eyes, and lateral to the digestive and reproductive organs. The posterior aorta divides into dorsal and ventral branches; the former to the muscles of the trunk; the latter, which divides into anterior and posterior branches, sending a vessel to each limb. These branches end in capillaries, communicating, however, with the perivisceral lacunæ, from whence the blood enters a

ventral vein, passing in the sternal canal to a central sinus, from which branchial arteries convey it to the gills, and from thence branchial veins pour it into the pericardial sinus.

The heart wall in Limulus and Decapods consists of several strata of striped muscle within a connective envelope, and at the orifices are passive valves. The heart is held in its place by elastic processes and radial *musculi alares*, which, by their contraction, dilate the vessel. In some Copepods the heart beats 100 times per minute.

Breathing may take place by the surface (Copepoda), by modified lamellary feet (Phyllopoda), or appendages of the feet, by pouch-like appendages of the thoracic segments (Amphipoda), or independent organs attached to the base of the feet, or by the mantle or lateral duplicatures of the skin in Entomostraca.

In Cirripedes the inner wall of this mantle is often folded into gill-like lamellæ between the wall and the base of the cavity. In Lepadidæ the hollow of these gill-folds becomes a brood-pouch. Others have gills variable in number and position, at the base of the cirri. Branchipus and Artemia have gills on all their feet. Apus on the anterior swimming feet. In Nebalia the respiratory and non-respiratory feet are sharply distinguished from each other; in others there is not much difference. In Isopods they are attached to the five abdominal feet as tile-like plates, of which, in Sphæroma, &c., one pair is differentiated and folded, or divided into strips (Ione). In Oniscus and Porcellio one pair is altered into gill covers, or the limbs of the last segment may form a cover (Idothæa); others are altered into vibratile organs which create currents in the gill cavity. In the terrestrial Porcellio and Armadillidium the anterior gill is air-holding. In Tylus four

Fig. 37.

Transverse section of Limnetis; *i*, intestine; *h*, heart; *n*, nerve ganglia; *b*, gills; *s*, shell.

pair have fine slits in them, through which air enters into cæcal tubes. In Stomapods the gills are fringes at the bases of the five abdominal feet. They are branched processes of the limbs of the cephalothorax, either floating freely (Thysanopoda), or roofed in by a process of the carapace according as they arise from the bases of the thoracic feet or from the body wall; in these cases, as swimming does not provide for a change in the water bathing the gills, there are thin, flat, external processes from the bases of the maxillipedes which create internal currents. In Amphipoda the 5–6 pouch-like gills are often covered by elongations of integument, sometimes closing in a perfect (Typhus), or imperfect gill cavity (Sergestes). In Poecilopoda the first pair of abdominal feet, by the basal union of their proximal joints, form an operculum, under which are the gills. Caprella has two short gills. In Lophogaster there are not only dorsal, but ventral gill filaments, projecting freely between the feet. Euphausia has the gills of the first pair of limbs as a single pouch-like process. In Decapods the gills are lamellar, twenty in Nephrops and Homarus, twenty-one in Scyllarus. The outer wall of the gill chamber has in some crabs a number of glandular swellings, which in Gecarcinus and other land crabs are large and spongy, and keep the gills wet. When the gills exceed the feet in number, the supernumerary lamellæ are attached to the first and second pairs of limbs.

The nervous system has long commissures uniting the pre-œsophageal with the post-œsophageal ganglion, and a ventral chain of ganglia, primarily paired, but usually united medially. The nerves often arise along with, and apparently from, the commissures.

The brain ganglia are small and separate, with a median commissure in the parasitic Copepods. In Lepadidæ the ventral chain consists of 4–5 ganglia, while in Balanidæ there is but one, compound, condensed. In Pœcilopoda there is a large pharyngeal mass, united by three commissures under the pharynx, and giving a double branch to the trigonal tail. In many Amphipods the size of the brain depends on that of the

eyes. When they are large, as in Phronima, the brain is large, while in eyeless forms it is exceedingly small; sometimes it is lobed (Oniscus). In the ventral cord of these there is often a considerable degree of fusion of ganglia, which are 10–12 in number, 7–13 in Isopods, 9 in Laemodipoda. In Decapods and Stomapods, as the mouth retreats from the eyes, the lateral commissures are often enormously long, and united in front of the hypopharyngeal ganglion by a transverse commissure.* In Stomapods there is an anterior small epipharyngeal brain, followed by the long united commissures, and a large cephalothoracic ganglion, the fused metameric ganglia of the peri- and post-stomial segments, from which the thoracic limbs derive their supply; then follow three abdominal, and six post-abdominal ganglia, of which the last is often large. In Schizopoda there are six cephalothoracic and abdominal, and six post-abdominal ganglia, and in Anomoura the post-abdominal ganglia are fused into one. In crabs all the post-oral ganglia form a hypopharyngeal central mass.

The antennar, antennular, and optic nerves arise from the brain; the auditory nerve varies in its origin. In Cirripedes there are two visceral nerves, one from the ventral ganglion, and one from the pharyngeal ring; these unite in a plexus. An azygos gastric nerve also exists from the ventral ganglion, and there is a corresponding nerve in some Branchiopoda. A cardiac nerve and ganglion exist in Limulus; but these are obscure in most Entomostraca. The number of ganglia is thus variable, the small numbers indicating concentration, not simplicity. The nervous system in Cladocera approaches most nearly to that of Vermes. Apus has the largest number of ganglia (two thoracic, eleven abdominal, and about forty-nine post-abdominal). Branchipus and Artemia have thirteen pair.

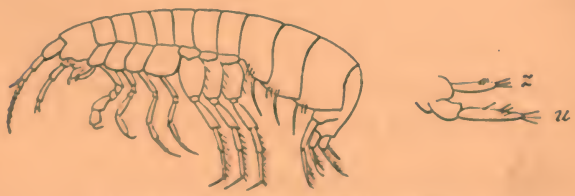
* Apus has a similar commissure.

Sense-organs are well developed in the higher Crustacea. The antennæ are organs of touch, and possess, near their points, groups of minute rod-like nerve-endings like short stiff bristles, into which nerves pass, and end in a granular protoplasm. Similar, but more elongated, bodies in the anterior antenna are supposed to be olfactory, or else a conical organ (in Decapods) at the base of the outer antenna, whose free end is either open or closed, may be an organ of smell. The olfactory rods are better developed in males than in females, and are sometimes pectinated.

The ear is a dermal sac, either closed, containing an otolith, or open, with a simple or complex mouth, sometimes containing a foreign body acting as an otolith. The cavity is lined with regularly disposed, stiff *acoustic hairs*, either attached to the otolith, and holding it in its place, or free at one end. These hairs have their shafts continuous with a delicate, superficial, chitinous layer lining the vesicle, and are only connected to the deeper structures by their axes. Similar hairs, like the sensory rods of the antenna, are found out of the vesicle.

The organ in Decapods is open at the base of the inner

Fig. 38.



Crangonyx subterraneus, a blind Crustacean.

antennule, and supplied by a branch of the inner antennary

nerve. Closed vesicles are found in the larva of the crab, containing an otolith, which is afterwards lost. They are also closed in Hippa, Pinnotheres, Hyas, Ocypoda, Gelasimus, &c. There is no ear in Crangon, Pandalus, Phyllosoma, Erichthus, Thysanopoda. In Mysis it is a closed vesicle, with an otolith attached by two hairs, and it is placed at the base of the inner appendage of the tail-fan, receiving its nerve from the last ganglion.

The eye is only absent in cave-dwellers like Astacus pellucidus of the Kentucky cave, and may be of several types. The essential part consists of a nerve fibre, ending in a long crystal cone, whose apex is directed inwards, merging into the nerve, and whose base is highly refracting and turned outwards. There is no special lens, but the chitinous integument is transparent where it covers the organ, which in the simplest case is quite free, and capable of sub-dermal motion.* Such single crystal cones exist in Copepod larvæ, one on each side of the brain; sometimes a cluster of these may be present (Corycæidæ, &c.), either medial, cyclopean, or bilobed. Sometimes two pair of these clusters are present, the outer of which may develop large crystal cones, while the inner fuse medially, and are rudimental, giving the appearance of three eyes.

In higher forms the chitinous integument becomes moulded on the front of the crystal cone as a corneal-lens, and is thus promoted into being a part of the organ. Usually several, or many such crystal cones, imbedded in pigment, are united, forming a compound eye. The corneal lens may be simple over the cluster

* In Argulus the eyes lie in a blood sinus in the head-shield. In many Copepoda a muscle passes from the wall of the orbital cavity to the eyeball to move it.

of cones, but is usually divided, each cone having its own hexagonal corneal lens or facet. Eye-like sense-organs, or, at least, red shining spheres, are distributed on the sides of the thoracic legs of some, or between the four anterior abdominal swimming feet. In Podophthalms the eye is mounted on an unjointed stalk, considered by some as a true limb.

Cirripedes are hermaphrodite, the ovaria and testes being branched pouches, only distinguishable by their products. In Barnacles the ovary is in the stalk, and is formed in an outgrowth of the mantle, into whose cavity it opens at the base of the first pair of cirri. In Balani they are imbedded in the mantle, the testes surround the digestive canal, and the vasa deferentia accompany the intestine, and often unite and open at the post abdomen. In free Copepods the ovary or testis is single, central, lying on the intestine. There are two oviducts, one on each side, opening either separately or together, and having their hinder part often dilated into a uterus, or having a series of egg-holding cæca (Corycæidæ). The wall of the last part is glandular, or a gland lies on it which secretes an adhesive material whereby the eggs are united in clusters, and carried by the female beneath the abdomen. There is often a terminal receptaculum seminis. Some parasitic Copepods have a double ovary, and the testes are either similar or single, with a double tortuous vas deferens, dilated at its end into a vesicula seminalis, in which the spermatozoa are cemented into spermaphores, and with a papillary end which may act as a penis. Sometimes the right vas aborts (Pontellidæ, Calanidæ). In Branchiopoda the ovary is either multilobar or a series of pouches along the intestine. In

Poecilopoda the ovary consists of long, tortuous, branched, and anastomosing tubes, those of the two sides united medially. In Isopods the ovary is long, saccular, with a median oviduct. In Oniscus the testis consists of three pair of pouches, which unite into one pair of vesiculæ seminales. Mysis and Decapods have a median ovary, with two large, lateral, saccular (Mysis), or lobate oviducts: these open at the base of the third pair of feet. In Anomoura the testes are abdominal. Some Stomapods have lateral pouches from the median ovary, and two or more oviducts which unite at a common sexual orifice. In Cirripedia and some Copepods, pigmy or complementary males are developed, with no digestive organs,* like those in Rotatoria. The spermatozoa may be globular (Phyllopoda), flattened (Palæmon), crescentic (Cladocera), thread-like (Argulus), radiated (Decapoda), sometimes dimorphic (Isopoda), and either amœboid or motionless. In Cyclopsine, Branchipus, &c., the antennæ of the males act as claspers.

In development the ova may undergo complete division, with no primitive streak, and form a larva or *Nauplius*, with an oval body, one eye, and three pairs of limbs. In higher forms the cleavage is only partial, a primitive streak forms from which the germ lamellæ extend, inclosing the unsegmented food yelk; the young becomes a *Zoea* with a spinose carapace, paired eyes, and post-abdomen. Sometimes both the Nauplius- and Zoea-stages are gone through before emergence from the egg.

* Complementary males are developed in the hermaphrodite forms Cryptophialus, Alcippe, &c., as in the diœcious forms, as Ibla, Scalpellum, &c. The male of Limnadia Hermanni is unknown.

CHAPTER XL.

SUB-CLASS I.—CIRRIPEDIA (*Burmeister*).

THE Crustacea are mostly marine; over 3000 species are known as now living, divided into the following sub-classes :—

Sub-class I. Cirripedia (*Burmeister*)—retrogradely metamorphosing Crustacea; sessile in their adult condition; fixed by the front of the head. The dorso-lateral integument is reduplicated around the body as a mantle, and the pre-ovarian cement (antennary?) gland pours out a secretion through the third or disc joint of the modified antennæ, whereby the body is anchored.* The hinder part of the body is free, lying in the mantle cavity, and protrusible, retaining six pair of prehensile, polyarthrous limbs, each with an endo- and exopodite. The mantle becomes calcified and chitinized in parts, forming a shell of several pieces, united by intervening soft portions. The body may be on a flat basis or stalked, the stalk or peduncle being soft, horny, flexible, composed of the front of the head, the cement ducts, and their secretion. The feet (cirri) and soft part of the body periodically moult, but the shell grows in successive layers, and is never cast.

The mouth lies in the mantle cavity, bordered by a pair of toothed mandibles and a palp-bearing clypeus. The maxillæ unite and form an under lip. The

* In Lepas fascicularis the abundant cement forms a basis for the attachment of a cluster of individuals, and may even form a float for them.

stomach is small, with hepatic cæca at its pylorus, and with two small, lobed, anterior glands, which may be salivary. The anus is between the two hindermost pair of cirri. The heart is a simple, tubular, dorsal vessel, with an anterior *sinus longitudinalis* (*Martin St. Ange*), but the peripheral circulation is lacunary; respiration is dermal, or in some Lepadidæ by lancet-shaped gills, or in Balanidæ by folds of the mantle lining. The larvæ possess simple eyes, which disappear at the first moult after the animal becomes sessile.

There are pigmy eye-bearing, saccular males, containing no organ but a testis, straight cirri, and adhesive antennæ, sometimes lodged in transverse pits in the shell of the female (Scalpellum). The young are minute *Nauplii*, free, oceanic, at first oval, pointed behind, with one or two pair of antennæ; the mantle layers then begin to form on each side, and the Nauplius becomes a cypris-like *Pupa*, which at the fourth moult becomes sessile, inclosed in the mantle; at the fifth moult eyes and antennæ disappear as such, being completely modified, the mantle calcifies, and additional abdominal limbs form, which develop into the cirri, while the mouth appendages and the post abdomen develop. Cirripedes are marine, found on stones, ships, and as oikosites on whales, fish, mollusca, &c. About 100 living species are known.

They are divided into four orders:—

1. Thoracica (*Darwin*)—stalked or sessile, with six cirriferous segments; a rudimental abdomen with post abdominal appendages; labrum not separately movable; pupa dodecapod. This contains three families:—1. Lepadidæ, Barnacles—peduncle containing the ovary and cement gland; shell laterally compressed, trigonal, with rounded angles, with (Lepas)

five calcareous plates, one dorsal, azygos (*carina*), two large, lateral, anterior (*scuta*), and two, small, posterior (*terga*); an adductor muscle is attached to the scuta, but all are separately movable on each other. Sometimes these pieces may be far removed from each other, and small (Otion), reduced to two, or even no calcified plates may exist (Anelasma), or the plates may be 20–100, the five principal being detectible (Pollicipes), or 15–20, indistinguishable (Scalpellum, the males of this form have 2-4, the females 15–20 plates). 2. Balanidæ—sessile, conical or cylindroidal, on a calcareous basis, which has the ovary and cement gland between its lamellæ; shell-pieces, 4–8, immovable in a circle, whose posterior (upper) opening is closed by a retractile operculum of two pairs of plates (scuta and terga), moved by adductor and depressor muscles. In this shell the lepadine carina forms an annular wall, within which the scuta and terga are prolonged, their posterior ends forming an operculum. The annular wall consists of two symmetrical, lateral pieces (*carina* and *rostrum*), with a thin, outer (*radius*), or inner (*ala*) lateral process; between the carina and rostrum there may be one pair of lateral plates, or two pair (*rostro-lateral* and *carino-lateral*). The rostrum sometimes has an ala, with a test of six (Chthalamus) or eight plates (Octomeris). The rostrum in others has a radius, and the shell may be all of one piece (Pyrgoma), or of four vertical plates (Tetraclita), or six, as in Balanus, or in the whale oikosite Coronula. 3. Verrucidæ—scuta and terga with no depressor muscles, movable at one side; on the other fused with the rostrum and carina.

2nd. Abdominalia (*Darwin*)—mantle compressed, conical, with a lateral opening (Alcippe), or flask-like, with terminal opening (Cryptophialus); with no calcareous plates, but with a broad adhesive disc; body, at least for its hinder part, segmented; labrum long, movable; cirri abdominal, three pair; diœcious, with pigmy males, of which two are attached to each female.

3rd. Apoda (*Darwin*)—mantle filamentary; mouth suctorial; body imperfectly segmented, with no cirri, ex. Proteolepas.

4th. Rhizocephala (*F. Müller*) — Suctoria (*Lilljeborg*); parasites on the abdomen of crabs; adults mouthless, saccular, elongated (Peltogaster), or transversely elliptical (Sacculina), membranous, filled by the ovary and testes, which appear to communicate; the end of the oviduct dilates into a brood pouch; the digestive canal has vanished (Sacculina has an œsophagus); foot-like tubes (modified antennæ or cement ducts) spring from the head and penetrate to the liver and intestine of the host. The larva is a tailed Nauplius, which develops a mantle and head tubes; then the nauplian feet are lost, and six pair of abdominal feet developed, which are finally lost. These are Cirripedes degraded by parasitism. In Thompsonia the larva seems to pass the nauplius stage in the egg, from which it starts as a two-eyed Cypridine larva (*Semper*).

CHAPTER XLI.

SUB-CLASS 2.—COPEPODA (*M. Edwards*).

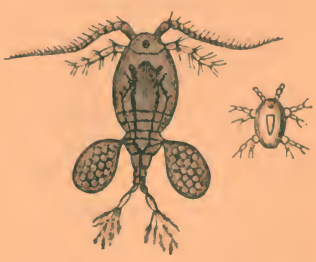
CRUSTACEA with a cephalothorax, a pair of jaws, two pair of maxillipedes, and one or two of abdominal feet, some of which abort in the parasitic forms; gills none, or leaf-like, abdominal appendages (Caliginæ). The free forms have movable and palpiferous mandibles, and two pair of antennæ, the anterior of which become rudimental in the parasitic species. The intestine is simple and straight. The sex-organs open on the fifth abdominal segment at each side, and the spermaphores are flask-like and left adherent to the mouth of the oviduct, where they remain even after they are emptied. The young begin life as Nauplii, the anterior pair of limbs becoming antennæ, the

hinder the mandible and maxillipede. The post abdomen bears a fringe of bristles, and often is split into rudder-like processes; many are acardiac.

Two orders are included:—

1. Gnathostomata—free, minute, marine, or freshwater, with developed jaws, and a moderate post-abdomen. This includes two families:—1. Cyclopidæ—first pair of antennæ long, oar-like, with (on the right only, Diaptomus) thickened clasping joints in the male; the female carries two (one in Diaptomus and Canthocamptus) lateral egg-sacs; eye either median (Cyclops, Diaptomus) or paired (Cetochilus, Sapphirina). The male Sapphirina is luminous. Cetochilus sometimes dyes the sea a deep red. Monstrilla, Calanus, Pontella, and Corycæa are often made types of subfamilies. 2. Notodelphidæ—parasites in the branchial sacs of Ascidians; body 11–12 ringed; in the females the fourth and fifth metameres are united, forming a brood-sac for the eggs; maxillæ many-cleft; first abdominal ring joined to the cephalothorax.

Fig. 39.

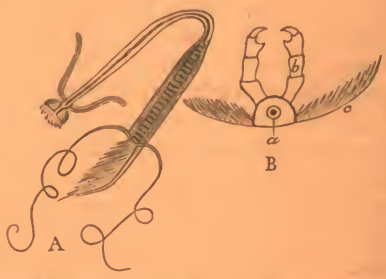


Cyclop quadricornis, with its two egg sacs. Nauplius larva.

Order 2. Siphonostomata (*Latreille*)—adults ecto-parasitic on fish, with suctorial mouths, soft bodies, and retrogressive metamorphosis; jaws reduced to bristles; thorax imperfectly or not segmented; front feet hook- or sucker-like; the males are often pigmy, and the females usually carry their eggs, like Cyclops, in two sacs. They include the following families:—1. Ergasilidæ—passage forms, the females only parasitic; body thick; antennæ jointed and bristled; second pair clawed; post-abdomen jointed, with bristle-bearing tail; abdominal feet removed from the medial line; the males in Nicothoë, &c., are Cyclops-like, and in the female (a lobster parasite) the abdomen forms on each side a long lateral sac, and the egg clusters are between these. The

pyriform Ergasilus lives on the gills of eels, Lichomolgus in Ascidians. 2. Argulinidæ—body flattened; cephalothorax and abdomen fused; post-abdomen small; eyes two, aggregate; two pair of maxillipedes; females with no egg-sacs; front antennæ hook-like, the second jointed; abdominal feet only cleft at the tip; liver multiramose; proboscis protrusible, with two annular poison glands; front maxillipedes forming suckers (Argulus) or hooks (Gyropeltis). 3. Caligidæ—flat; cephalothorax discoidal; post-abdomen small, often unjointed, with two terminal lamellæ. The front pair of antennæ are fused at base, and only the last two (Caligus, Dinemura, Pandarus) or three (Laemargus, Elytrophora); joints free; the mandibles are two stilets within the suctorial proboscis; the females carry egg-sacs. 4. Dichelestidæ—cephalothorax small, separate from the five abdominal somites; anterior antennæ free, many-jointed; second hook-like; males unknown; first pair (Dichelestium), or all the abdominal feet, two-branched (Kröyeria). 5. Chondracanthidæ—worm-like, with small cephalothorax, a rudimental pair of foot-jaws; abdominal feet leaf-like; males pigmy; abdomen unsegmented (Chondracanthus), or the three foremost joints united, the fourth narrow, and the fifth very long (Peniculus). 6. Lernæopoda — worm-like, with a pair of pigmy males on each female; body formed of two segments (cephalothorax and abdomen); the second pair of maxillipedes unite in a terminal sucker; cephalothorax pyriform (Achtheres), or worm-like (Anchorella, Tracheliastes). 7. Pennellidæ—worm-like, with a short, unjointed cephalothorax with unjointed limbs, lateral suckers, and minute abdominal feet. Pennella has a feather-like post-abdominal appendage (Fig. 40).

Fig. 40.



A, Pennella Orthagorisci. B, head magnified.

Sub-class 3. Ostracoda (*Latreille*)—free, microscopic, freshwater, or marine Crustaceans, whose hardened tegumentary folds form a bivalve, ventrally open, shell-like case, closed by an adductor muscle; they form one family. The body is of a bean-like form, often acardiac, with gills appended to the first and second pair of feet, while the third and fourth have none. The rudimental post-abdomen is unjointed; the eyes are two, single or aggregate; the two pair of tentacles are equal and bristled; the mandibular palps jointed. There is a crop with a cartilaginous bristled and folded ring around it, and the intestine has a convolution. There are six testicular pouches,* ending in a tortuous vas deferens. In the males the third pair of legs form claspers; the third and fourth pair of abdominal legs are absent in Cypridina; swimming feet in Cypris,† clawed in Cythere.

Sub-class 4. Branchiopoda—usually minute, mostly freshwater forms, the direct expansions of the Nauplius type, with 1–3 pairs of jaws, a distinct head, rudimental thoracic limbs, but a large abdomen, either homo- or hetero-nomously segmented, bearing 5–60 feet; a heart is always present, and the œsophagus rarely has a crop; the feet, or some of them, are flat, lobed, with gill appendages; the eyes are simple or compound, but never with a facetted cornea; the males are few, often with large spermatozoa, and impregnation precedes the deposition of the hard-shelled win-

* The viviparous Cythere has a lash-like spermatozoön, with one end broad, abrupt, and the other pointed, with a pedicle attached at right angle.

† In Cypris the spermatozoa are coiled, three times the length of the male animal.

ter eggs, while in summer pseudova are produced by parthenogenesis.

Two orders are included :—

1. Cladocera (*Latreille*)—including one family, short, compressed, with a two-valved shell, which does not cover the united large head and rudimental thorax. The front antennæ are small and palp-like, the second pair large, bristled, and cleft, acting as oars and as claspers in the males. The eye has often a ring of crystal cones around the central pigment mass, and a secondary eye may be present beside it. The unjointed post-abomen is bent down, with two claw-like processes. The gill feet are four pair (Polyphemus, Evadne), five (Daphnia, Lynceus), or six (Sida, Holopedium). In the females the eggs are received into a brood-pouch between the shell and the body posteriorly. Bosmina has two long frontal processes covered with sensory rods. The larvæ, on emission from the egg, have the adult number of legs ; 20–50 pseudova are laid by each female, but only 1–3 winter eggs, which are darker, with a compact yelk, and are surrounded by a second shell or *ephippium*, derived from the lining of the brood-pouch.

Order 2. Phyllopoda (*Latreille*)—elongate, with often a thin dorsal shell, but less perfect than in Cladocera ; eyes two, large, and one or two small, stalked or sessile ; abdomen many-jointed, tail-like posteriorly ; the thoracic limbs rudimentary or none ; the abdominal leaf-like, except the first pair ; mandibles without palps. Apus, Limnadia, and their allies have sessile eyes, and a shield-like (Apus) or bivalved mantle. Apus has two closely set eyes, two pair of rudimental antennæ, and sixty pair of branchiferous feet, of which the first is the largest ; the eleventh has two rounded valve-like flaps for holding the eggs, close to the sexual orifice ; the seven hindmost abdominal joints have no limbs. Limnadia has only 18–27 pair of legs.

The stalked-eyed forms have no mantle, eleven pair of gill feet, and a post-abdomen of 6–9 joints, with two movable end-lamellæ, at whose base the female has an egg-pouch, most are marine, Branchipus and Chirocephalus are freshwater.

Artemia lives in brine pools and salt lakes. Nebalia has a secondary binocular larval stage.

Sub-class 5. Trilobitæ (*Walch*)—palæozoic, shield-like forms of 6–20 somites, divided into three lobes by two longitudinal grooves. Cephalothorax semicircular, with two lateral compound eyes or none; between these is the *glabella;* outside them the *genæ;* below the glabella is the *labium* or *hypostome;* the middle lobe of the abdomen is called *rachis*, the laterals *pleuræ;* behind the abdominal segments is a post-abdomen whose rings are united, more or less, into a *pygidium;* the limbs are unknown; between the eye and glabella is a depressed area, the *fixed cheek*, and traces of the several component somites of the cephalothorax are often present as imperfect transverse sutures or grooves. The young was Naupliiform with unsegmented body. About 500 species are known, mostly Silurian.

CHAPTER XLII.

CRUSTACEA.

SUB-CLASS 6. Pœcilopoda (*Latreille*)—heteronomously segmented Crustacea, covered by two hard dorsal shields, one behind the other, the front one being convex forwards; eyes two, sessile, compound, far apart, on the front shield; cornea unfacetted; six pair of limbs around the mouth ambulatory, ending in pincers in the females,* and with their basal joints spinous, and acting as jaws; the five posterior pair are lamellar, gill-bearing and natatory. Two ocelli lie between the compound eyes; the pharyngeal nerve-ring is wide, with transverse commissures; the simple

* In the males the first (Limulus Polyphemus), or first and second pair (L. Moluccanus), have but one claw at the end.

nerve cord forks posteriorly; there is a trigonal, bayonet-shaped tail or telson; the mouth has a small labrum and a rudimental metastoma; the hinder shield or operculum is hexagonal; the natatory feet and tail are absent in the larva. The ambulatory legs consist of—1st, a modified pair of antennæ (the front, short pair); 2nd, a pair of mandibles; 3rd and 4th, two pair of maxillæ; 5th and 6th, two pair of maxillipedes. The third pair of thoracic limbs are expanded, and united medially, forming a flat plate over the five pair of swimming feet. The operculum corresponds to the post-abdomen of the trilobite, and has articulated to it six pair of marginal spines (post-abdominal feet), while the tail is the appendix of the last joint of the post-abdomen. The gills consist of 130–150 plates, like the leaves of a book, arising from the outer part of the coxopodite of each limb, which has, at its inner side, two lamellar terminal joints. The male has a small cylindrical penis. They are natives of the Moluccas and of N. America, and form one genus, Limulus.

Perhaps to this group belong the palæozoic fossils, Pterygotus and Eurypterus, which have many free thoracico-abdominal segments; eyes as in Limulus; mouth with a broad metastoma; antennæ one pair chelate; one pair of broad maxillipedes serrated at their bases; free abdominal somites, with no appendages.

Sub-class 7. Podophthalmia* (*Leach*)—heteronomously segmented Crustaceans, with twenty somites,†

* This and the succeeding sub-class are known as Malacostraca (*Latreille*), to distinguish them from the foregoing or Entomostraca; they have always thirteen thoracico-abdominal somites.

† Twenty-one, according to those who reckon the telson as a somite.

with compound facetted eyes on movable stalks; the three thoracic limbs modified into maxillipedes, and respiration by special gills. The *cephalogaster* (head, thorax and abdomen) is generally covered by a large calcified dorsal shield of two parts, an anterior or *cephalostegite*, often prolonged medially forwards into a rostrum, a posterior or *omostegite*. The sex-opening is at the ninth or eleventh post-oral somite, and all the post-abdominal segments behind this have special metameric shell rings. The antennæ are unequal, usually with divided filaments; the liver is consolidated, arborescent; development with a long metamorphosis.

Two orders are included:—

Order 1. Decapoda (*Latreille*)—Crabs and Lobsters; gills lamellar, in a cavity under cover of the cephalo- and omostegite, springing from the coxopodites of the hinder pair of maxillipedes, and of the five pair of ambulatory legs.* The oviduct opens at the base of the third, the male organ at the base of the fifth pair of legs. The segments of the head from before backwards bear the eyes, antennules, antennæ, mandible (with a 3–6 jointed palp†), and two maxillæ, respectively; the three thoracic segments bear three pair of maxillipedes, which overlap each other. The next pair is often large, with the hinder distal angle of the propodite lengthened so as to be capable of opposing the dactylopodite, so as to grasp objects when the latter is flexed by its powerful muscles; these are the pincers or chelæ. The second and third pair of abdominal feet have generally much smaller nippers. In all these the largest blade of the claw is internal. The fourth and fifth pairs have non-prehensile dactylopodites, and are usually seven-jointed. When the post-abdominal segments are movable their limbs consist of

* The processes from which gills spring on the limbs are known as *epipodites*.

† This is of use in directing food currents into the mouth.

a basal protopodite, bearing an endo- and an exo-podite, the latter of which, in the sixth or last post-abdominal segment is transversely divided into two joints. This segment also bears a flat terminal joint or telson, sometimes counted as a seventh somite.* In Astacus it is divided by a transverse suture.

The heart is short, polygonal, suspended by 3–6 elastic *alæ cordis*. The stomach is suspended by a muscular, partial mesogastrium from the front of the sternum, and from the base of the rostrum. The latter fibres are inserted into the cardiac ossicle† of the gizzard. In Macrura it lies directly beneath the part of the omostegite over the anterior abdominal segments, and behind the curved line on that shield which marks the contact of these somites with the posterior thoracic.

The gills are usually arranged in rows. In Macrura there are three series, the external largest, consisting of the leaf-like gills of the two hinder maxillipedes‡ and four foremost abdominal legs, the middle and inner of the branched gills springing singly in the second maxillipede, and occasionally from the last abdominal leg, and of pairs of similar gills attached to the epimeral plates at the bases of the basipodites of the intervening limbs. These organs are often much divided. There are three sub-orders :—

1. Macrura (*Latreille*)—post-abdomen as long as, or longer than, the cephalothorax, with limbs on all its segments, the last pair and telson expanded into a swimmer. The hinder pair of maxillipedes do not conceal the others. The embryo, before its maturity, has an exopodite on each of its ambulatory legs, like those which remain on the two hinder pair of maxillipedes.§ The omostegite is lengthened laterally into free,

* It is dorsal, and late in development, never bears limbs, nor a continuously calcified sternum, nor pleuræ, and hence is probably not a somite.

† The gizzard ossicles are—pyloric posteriorly, cardiac anteriorly, to the sides of which are attached pterocardiac ossicles, and behind them supero-lateral ossicles join these to the pyloric.

‡ On whose outer plicated surface alone gill filaments are developed.

§ The presence of this on the hinder maxillipedes has led to the discrimination of these from the anterior; thus, in the nomenclature of *Spence Bate* the two maxillæ and first maxillipede are the first, second, and third

even-edged, hair-margined pleuræ over the gills (*branchiostegites*). The post-abdominal pleuræ have smooth surfaces gliding on each other; those of the first and second overlap the preceding segments, while those farther back are overlapped by the pleuræ in front. The brain arises from the early fusion of six ganglia. The second maxilla has a spoon-shaped epipodite (*flagellum*, *scaphognathite*). A few develop with very little metamorphosis, others begin life as Nauplii, consisting of an anterior unsegmented part, with swimming bristles behind (head and swimmeret), and as growth proceeds intermediate parts form, producing a prosoma (thorax), mesosoma (abdomen), and a metasoma (post-abdomen). The following families are included:—1. Palinuridæ—Spiny Lobsters; pereiopods separated medially by a wide sternum; antennæ long (Palinurus), or flat (Scyllarus). The ovum develops from its nauplius stage into a Phyllosoma, or compressed, transparent pyriform larva, with stalked eyes, a wide cephalothorax, and a small segmented abdomen, with long thin legs. 2. Astacidæ—cephalothorax laterally compressed; post-abdomen flattened; anterior pereiopods large, chelate; gills numerous. The larva in Astacus only differs from the adult in the undeveloped tail; in Homarus in the presence of exopodites on the pereiopods, and the absence of some of the uropods. The freshwater Astacus differs from the marine Homarus anatomically in having fewer gills, longer hepatic cæca, a large undivided cæcal remnant of the umbilical vesicle, while Homarus has a smaller, bilobed sac; but it has a dorsal, single, rectal cæcum, which Astacus has not. Homarus has also an undivided telson and a small rostrum. Callianidea has respiratory appendages to the pleiopods. Nephrops is often sold under the name of Prawn. 3. Caididæ, Shrimps—shell horny, flexible; cephalothorax and abdomen laterally compressed; sternum linear; gills few; their larvæ have no cephalothorax nor post-abdominal legs; large

Siagonopods, while maxillipedes two and three are the first and second *Gnathopods*. The ambulatory legs are called by him *Pereiopods*, and the post-abdominal *Pleopods*; the hindmost three, when expanded, are called *Uropods*.

maxillipedes and small gills. In Crangon the two pairs of antennæ are closely approximated. In Alpheus the inner antenna is above the outer at origin, and the rostrum is small, or large, serrated (Palæmon). Troglocaris, from the cave of Adelsberg, is eyeless. Peneus, with small rostrum, has a distinct nauplius stage.

Fig. 41.

Hippolyte Gordoniana.

Sub-order 2. Anomura (*M. Edwards*)—post-abdomen small, nearly, or quite limbless, with soft terminal processes, not sunk into a sternal hollow; pterygostomial regions isolated by a suture from the cephalostegite; the fifth, or fourth and fifth, pair of pereiopods aborted; the last maxillipede large; the larva is a Zoëa (see next order). The families are:—1. Hippidæ—with a long cephalothorax; and 2. Lithodinidæ—with a crab-like cephalothorax; both these have a hard-shelled post-abdomen. 3. Galatheidæ have large chelæ and a roundish (Porcellana) or elongate (Galathea) cephalothorax, a moderate post-abdomen, and tail-fin. 4. Paguridæ—hermit crabs, have unequal chelæ, round, soft, post-abdomen, with a terminal sucker, imbedded plates, and 2–3 pair of soft, fin-like, rudimental feet; they hide this part in the deserted shells of

Gasteropods. Coënobita is a terrestrial form, which, in the West Indies, uses the shells of Bulimi. Pagurus is the common hermit crab. Birgus latro, the tree crab, is said to break open cocoa nuts.

Sub-order 3. Brachyura (*Latreille*) crabs—post-abdomen short, compressed, turned up in a hollow of the sternum under the cephalothorax, with no swimmeret on the last joint, and thread-like pleiopods; antennæ short; the dorsal surface is marked medially from before backward into gastric, genital, cardiac and intestinal regions, laterally into hepatic and branchial: the foremost pereiopod is chelate; the male post-abdomen is narrow, lanceolate; the female broadly ovate; between it and the sternum the eggs are carried in clusters; the foremost of the two rudimental pleiopods in the males is a clasper; in the female the same acts as a support organ for the gills, which are 7–9 on each side; the nervous system is concentrated into a single peripharyngeal ring. The larva or Zoëa is characterised by having a cephalothoracic shield with a central spine, and a long post-abdomen without appendages.

The following families are included:—1. Catometopa—cephalothorax four-angled; gills fewer than nine; male sexual orifice sternal. Ocypode has a flagellum from the ommatophore, continued past the eye, supposed to indicate the relation of the stalk to a limb. Pinnotheres lives between the valves of molluscs. Thelphusa is a S. European and N. African river crab. Gecarcinus, a W. Indian land crab, has between its gill lamellæ hard processes, which prevent them closing, and allow in air. 2. Cyclometopa—carapace oval, transversely elongate; gills nine; male sex-organs in the hip-joint of the fifth pereiopod. Cancer, the edible crab, has a serrated anterior edge. Portunus is rounded in front, and toothed laterally; the fifth pereiopod is natatory. Corystes is antero-posteriorly elongate. Carcinus has long postero-lateral edges to its carapace. 3. Oxyhryncha, spider crabs—carapace trigonal, pointed in front, an anterior proboscis. 4. Dromiidæ—fifth pereiopod smaller than the others, displaced dorsally; gills fourteen. Dromia is covered with brown hair. 5. Oxystomata—mouth triangular, not quadrate, as in the foregoing, with a rostrum in front; gills often only

six. The carapace is pyriform in Dorippe, semicircular in Calappa, round in Matuta, globular in Leucosida, obversely pear-shaped in Ranina.

Order 2. Stomapoda (*Lamarck*)—marine, with thin chitinous shell; gills branched, free at the base of the pleiopods, or none (Mysis), rarely on the cephalothoracic legs; the hinder thoracic resemble the anterior abdominal legs; the tail has a broad swimmeret attached to the last somite; development is from a *Zoëa*. There are three families:—1. Schizopoda—Omostegite reaching to the beginning of the post-abdomen, and in front covering the antennæ and eye pedicles; outer antennæ arising below the inner; all legs sub-equal; gills none (Mysis), or on all the eight thoracico-abdominal feet (Thysanopus). 2. Leuciferina—carapace small, but reaching to the post-abdomen; in front of it is a long head-process, on which the antennæ, antennules, and eyes are seated; the four hinder pair of limbs are simple, slender, and the post-abdomen linear. 3. Squillina—long, with small cephalothoracic shield, leaving the front of the head and the hinder abdominal rings free; gills on the post-abdominal legs; the second pair of thoracic legs large, its comb-like last joint shutting into a groove in the penultimate joint, like a penknife blade; the heart is long.

CHAPTER XLIII.

SUB-CLASS 8.—EDRIOPTHALMIA (*Leach*).

SMALL, but not microscopic Crustacea, with twenty body-somites, compound, sessile eyes, and rarely a carapace. Four orders are included:—

1. Cumaceæ (*Kröyer*)—marine, uniting many of the characters of Schizopoda with those of Edriophthalms; the short cephalothorax does not cover the hinder abdominal

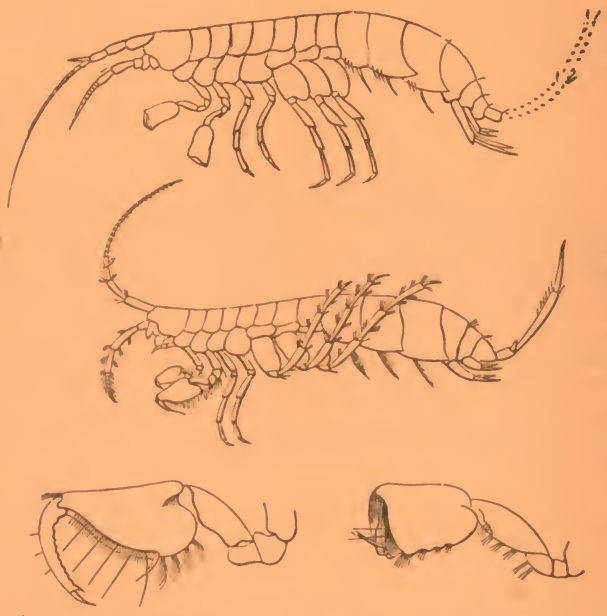
rings; one gill only is attached to the first maxillipede, under the pleura; there are no chelæ nor eyes; the inner antennæ are small, bicirrose, the outer large in the male, small in the female; the limbs shorten from before backwards, the four anterior in the males, and the first, or first and second in the female, have swimming appendages; the gills are simple expansions of the organs in Zoea, to which larval form this is the nearest mature ally; the eggs are large and few, and the larva emerges one-fourth the size of the mother.

2. Læmodipoda (*Latreille*)—post-abdomen rudimental, with obsolete appendages; head fused with the first thoracic ring, so that the front feet appear to be jugular. There are five pair of clawed feet, the third and fourth pair represented only by membranous gills on the bisegmented abdomen; the mandibles have no palps; the maxillæ are two-jointed. Two families are included:—1. Cyamidæ, whale-lice—body flat, oval; head small; upper antennæ four-jointed; gill vesicles on the abdominal segments in the female utilized as egg-bearers; maxillipedes united into a labium, and bearing palps. 2. Caprellidæ—body free, jointed, slender, with long three-jointed antennæ; penultimate joints of the first and second limbs thick; third and fourth absent; fifth, sixth, and seventh pair long.

Order 3. Amphipoda (*Lamarck*)—head and prothorax united, covered by a horny shell; segments nearly homonomous, laterally compressed; limbs seven pairs, two thoracic, and five abdominal; one pair of maxillipedes forming a lobate under lip; second and third pair of thoracic limbs prehensile; the four anterior abdominal are gill-bearing; post-abdomen with seven segments, and several feet with bristle appendages; the three hinder pair of abdominal feet are concave forwards, the others are convex forwards, hence the name; stomach with gizzard plates, and one or two pair of hepatic cæca; development is without metamorphosis. In the egg there is formed a larval membrane, separate from the chorion and inner egg-membrane, the remains of the nauplius carapace, which is lost at birth; a heap of cells extends from this to the back of the embryo (micropyle apparatus of *Meissner*),

the remains of the ancestral dorsal spine of the Zoea*. These transformations take place in the egg, and the young has assumed its adult form on its emergence.

Fig. 42.



Niphargus Kochianus; Niphargus fontanus.

The families are:—1. Gammaridæ—head small; antennæ many-jointed; maxillæ 4–5 jointed; some (Ceraphis) build nests of seaweed, &c., like Caddis cases, and most swim on their sides. Orchestia and Talitrus, Sandhoppers, have short antennules, and the third thoracic limbs chelate. Gammarus,

* The Ancestral Zoea was of the type of the Archizoea, whose descendant is the pupa stage of the Cirripede rather than the specialized Zoëa, of the crab. The preceding Nauplius resemble that of the Copepod (the Archinauplius).

the freshwater shrimp, has a large antennule and a mandibular palp. Lysianassa has no prehensile feet. Chelura terebrans bores into submerged timbers, 2. Hyperidæ—marine, often of extraordinary shapes; head large, thick; antennæ often rudimental; second maxilla three-jointed; all the limbs are prehensile, and the uropoda form a swimming tail; the body is not bent as in Gammaridæ, so they cannot leap. Phronima has only one pair of antennæ.

Order 4. Isopoda (*Latreille*)—integument membranous, rarely calcified; segments nearly homonomous, dorsally compressed; the two hinder thoracic limbs and the five abdominal legs equal, ambulatory; the post-abdominal feet lamellose; maxillipede forming a lower lip; the intra-ovular Nauplius has two trefoil-like side processes, representing the carapace, spines and gills of Zoea, but on emission from the egg the larva only differs from the adult by wanting the fifth abdominal pair of legs; the embryo in the egg is ventrally turned, as in Schizopods, not dorsally, as in Amphipods or most Decapods; the first thoracic segment is free from the head, except in Praniza, where the three thoracic segments and head unite; the gills are attached to the pleiopoda, each of which has external to it an epipodial membrane, which is delicate and respiratory in the aquatic, thick, tile-like protective in the terrestrial forms; the antennæ are four; the eyes often close together; the eggs are sometimes carried in brood-pouches attached to the legs; there is a mandibular, but no maxillary palp.

The following families are included:—1. Pranizidæ—with two large pair of antennæ; head and thorax fused; last pleiopod and telson forming a tail; ambulatory limbs five pairs; thoracic rudimental; the young and the female Praniza are suctorial and parasitic; the adult male is free, and has been described under the name Anceus. 2. Bopyridæ—male small, jointed; female broad, eyeless, unsymmetrical, with no mandibular palp, and a rudimental mouth; parasitic on other crustaceans (shrimps); males attached to the females, as in Siphonostomata. Bopyrus has in the female lamellose pleiopods; Ione has branched threads; Liriope is parasitic on the parasite Peltogaster; Cryptonisus is planaria-like, with

no segmentation, but has a segmented free-swimming young. 3. Cymothoidæ—feet (the three anterior pair in Æga) with claws; antennæ large; maxillipede operculate; head small; mostly parasites on the gills of fish (Cymothoa), or free (Serolis, &c.) The young Cymothoæ are free-swimming. Family 4. Sphaeromidæ—broad, shield-like, littoral; antennæ two pair, arising close together; head large transversely; legs simple; front ring of post-abdomen rudimental, united together; a swimming tail in some; they can roll themselves into a ball, except Cymodocea. Monolistra, from Adelsberg cave, is blind. Family 5. Oniscidæ (millepedes, slaters)—under stones in damp, not wet, places; oval, with rudimental or no antennules and mandibular palps; flat maxillipedes; feet all equal, ambulatory; post-abdomen six-jointed; its last segment with the pleopods modified into lamellæ or bristles; the foremost gill spaces have openings through their epipodial opercula, leading into canals, which are a form of tracheæ whereby air enters; the body is flatly compressed, not involuble, in Oniscus and Porcellio, and pointed behind in Ligia. Armadillo is more convex, capable of rolling into a ball, the last pleiopod with a large (in Armadillidium a small) basal joint. The recurrent nerve in Oniscus has an azygos ganglion frontale, as in Insects and Myriopods. Family 6. Idoteidæ, box slaters—body long, equally broad, cylindrical (Arcturus), or compressed (Idotea) throughout, with a short antennule, but no mandibular palp; post-abdomen with no posterior tail process. Family 7. Asellidæ—body as in last, but with a long posterior process on the shield-like hinder segment. Asellus is the freshwater millepede. Limnoria terebrans destroys submerged wood. The cylindrical Tanais has the first and second thoracic rings fused to the head.

CHAPTER XLIV.

DIVISION 2.—TRACHEOPNOA (*Schmarda*).

AIR-BREATHING Arthropods with one pair of antennæ, and either a cavity for the reception of air, or else a system of tubes (tracheæ) conveying it through the body. Three classes are included :—

Class 2. Arachnoidea (*V. der Hoeven*)—mostly terrestrial, with the head and thorax fused into a cephalothorax, bearing four pair of limbs. The abdomen is limbless, rarely with a post-abdomen, and the eyes are simple. The mandibles (as such) are absent, but their palps become developed in Scorpions as *chelæ*, or food-graspers, and the antennæ act as mandibles. The maxillary palps become the first and second ambulatory legs, while the third and fourth pair are the pro- and meso-thoracic limbs. Like Crustacea, they often moult, and at that time lost parts are restored. They do not part with their limbs as readily as Crustaceans, which, under circumstances of seizure or fright, often voluntarily sever one of their legs between the basi- and coxopodite.

The nervous system in the adult is concentrated, with short commissures, or may be simplified by the abortion of segments, as in Pycnogonidæ. In Scorpions the epipharyngeal ganglion is laterally constricted, supplying the stemmata, and sending two commissures to the limb-supplying hypopharyngeal ganglion, which consists of seven fused ganglia, three post-oral cephalic, three thoracic, and one abdominal: behind it are three abdominal and four post-abdomi-

nal ganglia, the last of which sends two branches to the end-claw of the tail.

Galeodes and Phrynus have two pharyngeal ganglia, from the hinder of which two medio-ventral cords pass to the somites, forming one posterior abdominal ganglion (often represented by a commissure), and two ventral cords, with a ventral ganglion. Pycnogonum and Tardigrades have four nearly confluent ganglia in the ventral cord (more separate in Nymphon). In Scorpions and Epeïra a visceral nerve springs from the brain, and passes along the œsophagus, on which it forms a ganglion. In Opilio the visceral nerve comes from the ventral ganglion, and forms many small ganglia. A similar nerve exists in many spiders.

There are no special organs of touch, of smell, nor of hearing. The eyes consist of clusters of crystal rods, largest in Lycosæ, covered closely with a convex corneal-lens. Pigment surrounds the cones in spiders, sometimes forming a tapetum, and even a ring or iris in front, around the surface of each cluster, along the margin of the cornea lens: in this are imbedded circular muscular fibres in some species. Scorpions have two large eyes close together, and laterally a group of 2–7, smaller. In Spiders there are eight in two rows. In Opilio there are three or four. Pycnogonum has four; others have two, and Pentastomum none. In some species of Trombidium they are stalked. The skin is generally soft, sensitive, never completely calcified, usually beset with hairs or bristles, rarely with scales; sub-dermal glands sometimes exist, as the two lateral organs of Adenopleura. The muscles of the body are yellowish, and remarkable vertical bands pass between the viscera, which they hold in their place. These fibres can make

temporary depressions, which have been mistaken for stigmata. The segments of the limbs are built on the Crustacean type, but the full series of seven are rarely developed. In some parasitic Mites the foot is discoidal. Oribates has postero-lateral dermal folds, like the mantle of Entomostraca, or the wings of Insects.

The mouth is often surrounded by a lip-like swelling, and armed with the antennary jaws, which are strong, hollow, with an opening on their inner side, into which the duct of a poison gland (the homologue of the shell gland of Crustaceans?) opens. In this duct are spiral muscular fibres, which squeeze out the poison. In Solpugidæ the first pair of feet becomes masticatory or prehensile. Salivary glands exist in the higher forms. Two pair of lobed glands are present in Scorpions, two convoluted pouches in Galeodes, several pair of small sacs in some Mites.* In Acarines the mouth is suctorial. There is rarely a pharynx, and the œsophagus is narrow, thick, sometimes with a chitin-lined longitudinal groove opening into the stomach, which is long, with its anterior part (stomach proper) elongated into cæca, which enter the limbs. Such caeca are two, rudimental in Scorpions and Phrynidæ, five pair in Spiders, entering the limbs and palpi. In Mygale the hinder pair branch and anastomose. In

Fig. 43.

Digestive Canal of Spider: *n*, nerve ring around œsophagus; *c*, cæca from the stomach; *l*, liver ducts; *r*, cloaca, with two linear urinary tubes opening into it (outside *l*).

* It is not easy to unravel the connexion between the poison gland of the antennæ and the salivary glands in spiders, but they seem to be quite separate.

Galeodes there are four, but the hinder send off lateral cæca, and two pair bifurcate, so that six pair enter the limbs and palps. In Pentastomum and Listrophorus there are none. In Mites there are eight, often branched, glandular cæca, in Phalangium as many as thirty, in several rows. Usually these do not extend beyond the first or second joint of the limb; but in Pycnogonum they stretch to the penultimate joint. Sometimes in Spiders these cæca unite into a ring-like stomach, extending backwards into the intestine, which in Galeodes also has one or more cæca: the rectum is globular in Spiders, or long, as in Scorpions. The liver may be absent (Pycnogonidæ, Pentastomidæ), or a granular envelope for the intestine (Ixodes, Adenopleura), or short, slightly branched pouches (Trombidium), or eighteen closely branched cæca in two groups, one anterior and one posterior (Galeodes),* or a large yellow-brown lobed organ with 2–3 (Spiders), or 4–5 (Scorpions) ducts on each side. In the last case it fills up a large part of the abdomen.

Opening into the rectum are, in Scorpions, simple or slightly branched canals passing between the lobes of the liver. In Spiders these canals are much branched, with two terminal ducts. In Phalangium and Acarus they are tortuous, unbranched. These may be urinary, homologous to the Malpighian tubes of Insects; they are absent in the Pseudarachnæ. Uric acid is found in two gastric cæca in Gamasus.

The fatty body is found in the abdomen of Mites and Scorpions, but is replaced by the liver in some Spiders. In Mites (Sarcoptes) it sometimes contains

* *Kittary* regards the hinder of these as renal.

uric acid concretions. In Scorpions the long, eight-chambered, tubular heart lies in a pericardiac sinus, suspended by alar ligaments or muscles, which help it to dilate; into each chamber venous blood enters through a pair of ostia protected by valves; out of the heart, in front and behind, pass arterial continuations of the heart, the anterior aorta, to the cephalothorax and limbs, the posterior to the abdomen; lateral arteries also arise from the heart. A supraspinal branch of the anterior artery runs along and supplies the nerve cord. Some organs seem to have capillaries, but the colourless blood also enters the insterstitial lacunæ, from whence it is collected in a sinus, and distributed to the air vessels by lacunæ, with no walls, and from thence it is poured into the pericardiac sinus.

Spiders have an abdominal heart, with three pairs of ostia, but no pericardial sinus nor capillaries; the anterior aorta bifurcates into lateral branches; the posterior ends abruptly by a free mouth. Pycnogonum has a two- (or three-) chambered heart, with two pairs of ostia. Mites and Tardigrades are acardiac.

Respiration takes place by the dermis in many Mites, but usually by tracheæ, which are tubes placed symmetrically, opening on the surface by lateral, transversely oval holes (*stigmata*), and carrying air into the interior of the body. These tubes consist of a connective basis, continuous with the dermis, lined by a chitinous cuticle, which, by its elasticity, keeps the tube open. When well developed, this lining thickens into a spirally-coiled thread, here and there interrupted by the sacculation of the tube. The stigmata are surrounded by chitinous rings, and usually

protected by circles of hairs, and sometimes have valves moved by muscles. The tracheæ branch and end in a network around the viscera; sometimes large branches coalesce, making longitudinal or transverse air channels through the whole body. In Arachnida the tracheæ are usually incomplete, and only in limited regions of the body. Their branches are usually fasciculate. Trombidium has one pair, as has Phalangium, in which they are freely branched. In Galeodes there are three pair. In the short dilated tracheæ of some, the lining membrane is dilated into many (60–100 in Scorpions) book-leaf-like plates, whose interspaces receive air from the stigmata; these are called tracheal-lungs, but they are only closely compressed tracheæ with the lumina of their tubes flattened. Many intervening gradational forms exist. Of these, one or two (Mygale) pair exist in Spiders; two pair in Phrynidæ; four pair in Scorpions, in the four anterior abdominal segments. In others a pair of tracheæ, with no spiral thread nor branches, co-exist.

Beside the poison gland of the antennary jaws, and the lateral glands of Adenopleura, there is a pair of tail glands in the Scorpion, opening at the base of the tail claw. The spinning gland of the spider consists of several pair of abdominal glands, opening on the flat spinning field, or an eminence below the anus, by ducts which can be opened or closed at will, these secrete a material which, when extended and exposed to the air, becomes chitinoid. There may be two (Mygale), three (most genera), four (Drassus, Clubione) pair of spinning warts, on each of which many (400 in Tegenaria, 100 in Segestria, 1000 in Epeira) ducts open, hence each thread consists of hundreds of

strands. The material is extruded suddenly and in large quantity, especially when the female lays eggs; the material is arranged by the comb-like claws.

All but Tardigrades are diœcious; the testes are single or clustered cæca. The vasa deferentia open far from the anus, at the base of the abdomen, between the stigmata, and in this bilateral termination they resemble the Chilognaths. Accessory saccular glands secrete the adhesive material which makes spermaphores. The only intromittent organs are the wart-like processes in Scorpions, the protrusible penis of (Phalangium), which corresponds to the ovipositor of the female, and has two large branching bristles at its end, the double spiculum of Pentastoma, or the single one of some mites. In male spiders the spoon shaped last joint of the maxillary palp places the spermaphores in the female vulva. The ovary is tubular, with grape-like eggs on a central rachis, or rarely in a ring round it (Phalangium, some Mites). In Scorpions (which, like Phrynus, are oviparous) the ovary consists of three azygous communicating tubes. In Phalangium the two oviducts unite, and a duct passes to the protrusible ovipositor; a similar organ present in some Mites. Parthenogenesis is described in Cheiletus. Tardigrades have a median epi-intestinal ovary, two lateral testes, each with one vas deferens and a common receptaculum seminis. In Galeodes there are two ovaries, as in Spiders. Many Mites have an imperfectly annular ovary, and Pentastoma has a long ovary ending in two oviducts united by an annular canal. From thence comes a single canal dilated into a uterus, which ends at the vulva. Where

this arises from the ring are two receptacula seminis. In males the testes also end in a ring vessel.

In Pycnogonidæ the sex-glands have no ducts, but their secretions are emptied into the body cavity, from whence they escape by openings at the bases of all, or one pair of legs.

Development begins, except in Pseudarachna, by a partial segmentation of the yelk, and the formation of a primitive streak at the ventral side of the embryo; the young early assume their adult form; many mites are at first hexapod, until after several moults. The young Pycnogonum has an unjointed body, and two or three pair of two- or three-jointed legs. Pentastomum retrogrades in development. The embryo of Ixodes and of scorpions possess the Micropyle apparatus of *Meissner*, indicating their relationship to Archizoea.

Arachnida are divisible into two sub-classes:—

Sub-class 1. Pseudarachna (*Haeckel*)—retrograded forms, with complete yelk-division; no tracheæ, liver, nor renal tubes; a small epipharyngeal ganglion and a ventral cord of four approximated ganglia. The orders included are dissimilar.

Order 1. Pantopoda (*Burmeister*)—marine or littoral; integument chitinous; abdomen rudimental, peg-like, unjointed; cephalothorax four-jointed, bearing four pair of long 7–9 jointed, claw-bearing legs; rarely shorter (Zetes); usually as long as, or longer than, the body; antennary jaws sharp or none (Pycnogonum); mandibular palp 4–5 jointed (Nymphon), or none (Pycnogonum); ocelli four on a frontal ridge. The narrow œsophagus has three flat, bristled ridges; the stomach five pair of long glandular cæca, the front, short pair stretching into the antennary jaws; the testes open at the end of the first or second joint of the divided meropodite, in which the gland lies; the ovaries lie in the same segment, and open

at the base of the coxopodite, where there are accessory legs for attaching the ova. There is one family, Pycnogonidæ, and seven genera; some are fish-parasites.

Order 2. Tardigrada (*Dujardin*)—hermaphrodite, minute, worm-like, acardiac, with soft skin; cephalothorax and abdomen fused; four obscure metameres, and four pair of short legs, rudimental, each with three or four curved claws; the last pair of legs terminal; mouth suctorial, on a fleshy tube, with two salivary glands, and the antennary jaws forming two piercers, with protrusor and retractor muscles; œsophagus gizzard-like; stomach large, with many grape-like cæca; ocelli two; the single ovary and the lateral testes open into the cloaca; ventral ganglia are further apart than in the last order. They live in damp moss and gutters, and can bear drying with impunity, like Rotifers. They lay a few large eggs during the moulting process, and the slough acts as an egg sac. There is one family Arctisca. Macrobiotus has no palps or bristles. Echiniscus has marginal bristles. Milnesium is palpate, but with no bristles. Emydium has both.

Sub-class 2. Autarachna (*Haeckel*)—true Arachnids, with a developed abdomen, rarely undergoing retrogression, usually with respiratory and excretory organs, and ova with partly cleaving yelk. Three orders are included:—

Order 1. Acarina—soft-skinned, with unsegmented abdomen, united to the cephalothorax; ocelli none or two, rarely more; respiration tracheal or dermal; mouth either masticatory, with claw-like antennary jaws, or suctorial, the rostrum or sucking tube being the united pair of mandibular palps, containing the stilet-like antennary jaws; ventral cord, with one ganglion; anus ventral; legs four pair, each with two end-claws; digestive canal simple, or with cæca, which are often bifurcate at their end, sometimes all directed forwards. There is no heart nor separate liver (except the grape-like cæca in Trombidium, &c.). The tracheæ have often few branches or none, no spiral thread, and one pair of stigmata at the bases of the antennary jaws, or of the third or fourth limb-pair. The sexual opening is simple, preanal, often far forward, and the oviduct is often widened into a uterus. The vas

deferens may have accessory glands (three pair in Argas). The young are generally hexapod. Eight families are included: 1. Pentastomidæ—nearly colorless, worm-like endoparasites from the internal cavity of Vertebrates, with a long annulated body; beginning life as an ovate embryo with two pairs of short, two-jointed, two-clawed feet; mouth with two hook-like antennary jaws; this larva becomes pyriform, a tail forming, with terminal bristles, and after a few moults the hooks are lost, and are followed by others which form an anterior series, two on each side of the mouth. The worm-like adult has a simple digestive tube, with villiferous ridges internally and a terminal anus. The mouth has a chitinous ring and a pair of small salivary glands. The testis is single, sub-gastric at the anterior one-third of the body; the two vasa deferentia are united at their origin, each passes forwards convoluted, and ends in a long penis, coiled when at rest, and included in a sac projecting near the anterior end. The ovary is long, simple, over the stomach, with its oviducts opening anteriorly into a sac, beside the pharyngeal ganglion, which communicates with a pair of large oval lateral receptacula seminis; from this sac one or two vaginæ pass backwards, opening preanally. There are stigma-like pits, but no tracheæ. There is one family and genus. P. tænioides inhabit the nostrils, &c., of dogs; P. imperatoris and proboscideum, the lungs of the boa, &c. They are the only Arthropods with a continuous clothing of longitudinal muscular fibres, which, like the muscles of the intestine, are striped. There is an œsophageal nerve ring. The larvæ of some are encysted in the liver of the hare, &c. P. constrictum has been found in the human liver. 2. Acaridæ, Mites—minute, oval or elongate, with soft body and chitinous supports for the short legs, which have each two claws, and often an adhesive disk; mouth mandibulate or suctorial; ocelli and tracheæ none; often parasitic. Demodex, from the human sebaceous follicles, has a worm-like, unringed abdomen. Sarcoptes, the itch insect, has an oval, undivided body, and the feet all (in the males), or the foremost two pair (females), with suckers; the back bears conical processes, and the male has three testes and a spiculum. Acarus, the cheese and flour mites, have scissors-like

antennary jaws. Glyciphagus lives on feathers, &c. Dermatodectes on horses, sheep, &c. 3. Ixodidæ (ticks)—body leathery or horny, extensile, antennary feet piercers, with recurved hooks; palps 3–9, jointed, in I. Gervaisii with a sucker on the last joint; legs two-clawed; eyes two or none. They live in bushes, and attach themselves to passing animals, whose blood they suck, whereupon their bodies swell immensely. The first pair of maxillæ, at their bases, form a kind of underlip, ring-like below. The sex-openings are far forward. Argas has a rough dorsal surface and two terminal hooks on the antennary feet. Ixodes is smooth, dorsally, with (Hyalomma) or without eyes (Amblyomma). Adenopleura, from the pangolin, has a flattened body, a serrated hinder margin, and two lateral glandular sacs. The claws have an oval cushion or caruncle at their base. The dorsal integument is covered with closely undulated ridges. 4. Gamasidæ, Spider mites—eyeless; feet equal, hairy, two-clawed, and with a sucking disk; antennary jaws scissors-like; palps free, the joints equally long; body undivided; parasitic on beetles (Gamasus), reptiles, and birds (Dermanyssus), but not fastened by a piercing beak. Pteroptus with a long end-joint to the palp; lives on bats. 5. Oribatidæ—viviparous, grass and wood mites, hard and horny, cracking like glass when pressed; antennary jaws, retractile; no ocelli; feet with 1–3 claws; back shield often with wing-like lateral folds and two suckers at the border of the cephalothorax; palps four-jointed. Nothrus has a four-angled body, and thick three-clawed legs; Phytoptus lives on vine leaves; Leiosoma, Hoplophora, &c., on other vegetables. 6. Hydrachnidæ, Water-mites—legs often finely bristled; body undivided; eyes two; antennary jaws claw-like (Atax), or sharp-pointed, needle-like (Hydrachna), or bristle-like (Limnochares); palps short, bristled or hooked at the end. The young are suctorial; parasitic on water insects. Pontarachna is marine. 7. Trombididæ—soft, brightly colored, undivided; ocelli four (Erythræus), or two (Tetranychus); antennary jaws, claw- (Trombidium), or needle-like (Tetranychus); palps scissors-like. Trombidium is parasitic on Aphides, &c. Tetranychus telarius secretes a web on the leaves of lime-trees. 8. Bdellidæ—brightly colored; body

constricted at the origin of the first pair of limbs, and also behind the head; ocelli 2–6; legs equal; long, thin, with separate claw-joints, living in damp earth.

Order 2. Araneina, Spiders—having the unjointed cephalothorax and the saccular abdomen united by a narrow peduncle; breathing by tracheal lungs and tracheæ; mouth masticatory, rarely with no labium (Aphantocheilus); antennary jaws pierced by the poison duct; eyes 6–8; spinning warts posterior, rarely only two (Stenochilus Hobsoni); stomach annular, surrounded by the voluminous liver. There are usually two tracheæ behind the tracheal lungs, and the sex-openings are between the lung stigmata. The non-chelate palps are simple in the female, but in the male they are swollen at the tip and grooved beneath, and have several hook-like appendages; by these the spermaphores are placed in the female vulva. They are predaceous, with often comb-like paired claws, and undergo no metamorphosis, but moult frequently. There are two Sub-orders:—1. Tetrapneumones (*Latreille*)—with four lungs and stigmata, and four spinnerets, of which two are small; ocelli eight, close together; large spiders, forming one family, Mygalidæ, with long, foot-like palps, with two end claws; many of them dig burrows, which they line with web-material, and for which they form a lid fastened by a silken hinge (Cteniza, Atypus, &c.). Mygale, with down-directed antennary jaws and screw-like copulatory palp, is said to attack small birds. Sub-order 2. Dipneumones (*Latreille*)—lungs two; stigmata two or four; in the latter case, as in Segestria, Dysdera, &c., the hinder pair open into tracheæ; spinnerets three pair; antennary jaws, with indirected claws; ocelli scattered. The families are: 1. Araneidæ—sedentary web-spinners, with ocelli in two transverse rows: some are tube- or flask-spinners (§ Tubitelæ), having the second and third pair of legs shorter than the first and last. Dysdera has four eyes in the first row, two in the second. Nops has but two eyes. Segestria has three rows, each of two eyes. Drassus has eight unequal eyes. Clubiona has eight eyes, of which the four hinder and two extreme of the front row form a crescent. Argyroneta (the water-spider) has straight rows, Tegenaria (the house-spider)

two slightly curved rows of ocelli. Some (§Orbitelæ) spin geometrical webs, in whose middle they lurk; their first and second pairs of legs are longer than the fourth, and they have eight ocelli either in two transverse lines (Tetragnatha), or the four medial in a square, and the lateral on the edge of the cephalothorax (Epeira). Gasteracantha, Mithras, and Acrosoma (S. American), have the abdomen very broad, and often with long lateral horns. Other Spiders are either Laterigradæ, spinning single threads, living in web-united clusters of leaves, and moving sideways (Thomisus), or else Inæquitelæ, resembling Thomisus in having the first pair of legs the longest, but spinning irregular webs, whose threads cross each other in inconstant directions, as in Pholcus, which has its outer, or Theridion, which has its inner, ocelli the largest. Family 2. Lycosidæ—wandering or hunting Spiders, spinning no webs, but the females carrying egg-sacs; ocelli in three rows; some have a cephalothorax narrowing in front, with the second (Dolomedes), or fourth (Lycosa, the Tarantula) pair of legs the longest. Others have a square cephalothorax, and leap on their prey (Salticus, Eresus). Myrmecia is ant-like in shape.

Order 3. Arthrogastra (*Gerstaecker*)—abdomen sessile, segmented; mandibular palps developed as pincers or *cheliceræ*. They are divided into five Sub-orders, each containing a single family.

1. Phalangita (*Gerst.*) Opilonidea (Harvest-men)—short-bodied; abdomen thick, transversely folded, or six-jointed; cephalothorax unsegmented; respiration tracheal; cheliceræ three-jointed, with no poison gland; ocelli two (the so-called hinder pair are said by *Krohn* to be gland sacs); third and fourth feet two-clawed; first and second, one-clawed. The female has an ovipositor. Hermaphrodites have been found producing small ova in the lobes of the testis. They hunt their prey. Cyphophthalmus is a blind cave-dweller, with eight abdominal rings. The hind legs are often, in S. American forms, large and curiously bent (Gonyleptes). Trogulus and Phalangium are European.

2. Pseudoscorpiones (*Latreille*)—small, flattened, cylindrical, or pear-shaped; abdomen eleven-jointed, with spinning

glands; rudimentary, membranous antennary jaws, but large chelicerous mandibular palps; they have a coiled intestine and tracheæ; ocelli 2–4 (Obisium). Chelifer has a groove on the cephalothorax, and is common in old books, on flies, &c.

3. Scorpiodea (*Gerstaecker*) — cephalothorax unjointed; abdomen of seven segments, with a six-jointed post-abdomen; mandibular palps as very large cheliceræ, with the inner angle of the propodite elongated, to meet the dactylopodite; antennary jaws also claw-like; respiration is by tracheal lungs, with four stigmata on the ventral side of the third to sixth abdominal ring, surrounded by raised edges or *peritremes*. The last body-segment is narrow, cylindrical, with a terminal perforate claw and poison-gland; a pair of comb-like appendages (modified legs ?), with down-directed teeth, lie at the base of the abdomen behind the last pair of legs; these are supposed to act in copulation (in the male) and oviposition (in the female). The males have more teeth in these combs than the females; they also have a longer post-abdomen and flatter claws. They are viviparous, and produce 20–60 at once. Heterometrus afer reaches six inches in length.

Sub-order 4. Pedipalpi (*Latreille*)—spider-like, with a terminal claw on each two-jointed maxillary palp; mandibular palps with unequally long chelæ, not capable of closure, as the angle of the propodite is not sufficiently prolonged; eyes eight; abdomen with 11–12 segments, and no post-abdomen, and four tracheal-lungs on the second and third abdominal rings. Phrynus is viviparous. The abdomen and thorax are more distinct than in true scorpions. There is no comb-like appendix, nor poison apparatus. Thelyphonus has the three hindmost joints of the body slender, ending in a long-jointed tail process, and has an oval cephalothorax. Phrynus has leg-like chelæ and no tail. Nyctalops has a divided cephalothorax, the first segment elongate, bearing the two anterior pair of legs; the hinder smaller.

Sub-order 5. Galeodea—cephalothorax four-jointed; abdomen long, ten-ringed; antennary jaws scissors-like, with no poison-gland, but a vesicular dilatation at base; tracheal stigmata on the second and third joint; an abundant hair

clothing, &c.; the leg-like maxillary and mandibular palps have no claws. Sternum broad, with a mesial groove; legs with two long claws each; ocelli one pair; crescentic stalked processes arise at the origin of the hindmost pair of legs, which may be homologous to the combs of the scorpions. Galeodes (Solpuga) inhabits S. Europe and Asia.

CHAPTER XLV.

CLASS 3.—MYRIOPODA (*Gerstaecker*).*

ARTHROPODS with a distinct head, one pair of antennæ, tracheæ, and a long cylindrical or flattened body of 9–160, nearly homonomous, limb-bearing somites. Each metamere has a ring of chitinous or calcified (Julus) integument (Chilopoda), or the rings of each pair of segments are confluent, or the rings may be only partially chitinized as dorsal, or dorsal and ventral plates. The subulate or filiform seven- or many-jointed antennæ arise under, rarely over, the frontal plate, and have many single or clustered sensory-rods. The mouth is ventral, surrounded by a lip. The hook-like mandible bears a movable palp on the chewing surface. Both pair of maxillæ may unite mesially to form a lower lip (Chilognatha), or the second pair alone may unite (Chilopoda), or may be absent. There is no distinct maxillary palp. The ventral ganglia are paired, homonomous, 8–16 (Lithobius), 22 (Scolopendra), 140 (Geophilus), united by commissures; there are two epipharyngeal ganglia joined by a commissure, and giving off optic and

* Myriapoda of Leach and older writers.

antennary nerves. The ganglia of the post-oral head segments unite into a hypopharyngeal ganglion in front of the ventral cord. In Iulus the ventral ganglia are confluent, so the entire cord has a coating of ganglion cells. A visceral nerve from the epipharyngeal ganglion unites with its fellow on the œsophagus, forming a ganglion, from which an azygous branch passes backwards, forming visceral ganglia, communicating with lateral œsophageal branches from the brain ganglion also. Other visceral twigs arise from the ventral ganglia. A delicate peritoneal layer, containing transverse muscular bands, keeps the ventral cord in its place, and in the fatty, concretion-holding body, at each side of it, is a longitudinal blood sinus. In Polydesmus, branches seem to arise from the commissures. There are no otocysts. The eyes may be compound, with a facetted cornea (Scutigera), or simple, in one or two rows, or in a cluster on the upper or lateral part of the head ; rarely absent. The optic nerve has a special ganglion.

The œsophagus is narrow, with one pair of simple (Iulus), lobed (Lithobius), or three pair of grape-like salivary glands (Scolopendra) ; the stomach is cylindrical : the intestine straight, often dilated, or convoluted (Glomeris), with a posterior anus ; the gastric gland-cells may be hepatic, as there is no other liver ; the urinary tubes are tortuous, thread-like, two (Iulus) or four (Scolopendra), like those of insect-larvæ, opening into the rectum.

The heart is long, with a chamber for each segment,* separated from its fellows by valves, and with

* Not always. In Iulus, although this was the embryonic condition, they unite in pairs, so each chamber giving off two pair of branches, in each segment.

a lateral row of venous ostia; it is kept in its place by triangular musculi alares attached to the body wall, and gives off from each chamber a pair of arteries for each somite. The front chamber sends off medially a cephalic branch, and on each side a branch which surrounds the œsophagus as a pair of rings, which uniting form the large blood sinus that accompanies the ventral nerve cord (thus like the arrangement in the Scorpion). There is no venous nor capillary system, nor a pericardial sinus, but the blood flows in lacunæ and perivisceral spaces.

The paired tracheæ open ventrally or laterally, and may be equal to (Geophilus), or fewer than (Scolopendra), the number of segments. In Iulus a bundle of simple or slightly branched non-anastomosing tubes passes from each stigma; in Glomeris they are branched; in Scolopendra they have free longitudinal and transverse anastomoses; in Lithobius and Scolopendra, stigma-bearing and stigma-less segments alternate.

Scattered on the surface are often, pear-shaped glands, secreting a brown, corrosive fluid, with a very disagreeable smell, opening by dorsal pores (foramina repugnatoria). The thorax and abdomen are not differentiated, and each segment bears ventrally, either near the middle line or laterally, 1–2 pair of 6–7 jointed legs, which on all segments are alike, with single or double end-claws.

They are diœcious, oviparous. The whole yelk cleaves, and the food yelk lies outside the wall of the alimentary canal, between it and the integument. The ovary is either a single pouch, with a single or double oviduct, or is double (Craspedosoma), united anteriorly,

but with two oviducts opening separately. Opening into the vulva, rarely into the oviduct, are two stalked receptacula seminis and a pair of cement glands, whereby the eggs are stuck together. The testes are double (Iulidæ, Glomeris) or single, with, in the former case, one vas deferens between them; in the latter a series of lateral pouches communicates with a central convoluted vas deferens, which dilates or divides into two, which either open separately on small papillæ, or again unite, and form a small penis; 1–3 pair of accessory glands, for the secretion of adhesive matter to make spermaphores, are appended to the end of the vas, as well as vesiculæ seminales. The females are larger than the males. The genital openings are posterior in Scolopendra, or between the second and third body ring in Chilognatha, in which sometimes the male has a double spiculum on the seventh segment, which carries the spermaphores from the opening of the vas to the female vulva. The ova are laid in the ground, and in development form two germ-layers, an outer *neuro-epithelial*, and an inner, which divides into many protovertebra-like bodies, giving rise to the muscular and other systems. The primary neural region in the egg is concave, and the embryo is invested with a structureless larval skin, like that of Crustaceans and Acari. The larvæ are apodous or hexapod, and the number of legs increases at every moult, and the eyes and antennæ afterwards develop; the terminal rings are the first developed, then the intermediate. Some Scolopendra are viviparous. The bite of some is poisonous, as the foot-jaws have a poison-gland. They are largest in the tropics.

There are three orders:—

Order 1. Chilognatha (*Latreille*)—cylindrical, or semi-cylindrical, with two pair of legs on every segment after the fifth or sixth; thoracic rings with free dorsal plates; each segment has a stigma in front of the articulation of each leg; often very small, except in Polydesmus; the genital orifice is between the second and third ring, the latter of which has no legs; the small antennæ consist of seven joints, the last often hidden in the sixth; the coxopodites of the first pair of legs are directed forwards, and partly unite to form a labium. In development new segments arise between the third last and second last segment of the hexapod larva. The number of somites is not always specifically constant, and the shell of each joint is either a ring or half ring, in Glomeris allowing the body to be rolled into a ball; sometimes the ventral plates are divided, and extended laterally as laminæ pleurales. The first thoracic ring has no limb in Polydesmus, and when the seventh ring bears the penis it has no limb. In Iulus the two testes are united by transverse anastomoses; on each side of the back on all (Iulus, Polyzonium), or some segments (Polydesmus), are *foramina repugnatoria*.

Three families are included:—1. Glomeridæ—wood-louse-like, short, concave below, semicylindrical, with either twelve segments and seventeen pair of legs (Glomeris), or thirteen segments and twenty pair of legs (Sphærotherium); each ring has one dorsal and four ventral plates, the lateral of which (laminæ pleurales) articulate with the legs; the first ring is small, covered by the second, the last is shield-like; the spicula are pre-anal, placed far back. 2. Iulidæ—cylindrical; ventral and dorsal plates united in a suture; head large, free; first thoracic ring not covered by the second; last ring compressed, with an anal slit. The eyeless Polydesmus and Strongylosoma have twenty rings; Polyxenus has nine. They have also a sternal space between the origin of the legs, and a lateral plate, or ridge, or bundle of hairs. Iulus has fifty, Lysiopetalum forty-five rings, and the limb-pairs medially in contact. Spirobolus reaches a length of nine inches. 3. Siphonizantia—bodies semi-cylindrical, capable of being spirally rolled up; head small, hidden under the first body ring;

mouth prolonged into a sucking tube; the body covers the limbs; surface smooth (Polyzonium), or rough, and 70–, 80-jointed (Siphonophora).

Order 2. Chilopoda (*Latreille*)—somites flattened, each with a dorsal and ventral plate, and not more than one pair of limbs; antennæ of more than fourteen joints; generative organs posterior. The third thoracic ring has a free dorsal plate; so has the second in Lithobius and Geophilus; penis none; stigmata lateral; the first and second pair of legs converted into foot-jaws, the hinder of which is perforated by the poison-duct, and claw-like; the stigma pairs are fewer than the somites. The larvæ may have 6–8 pair of legs, and new segments arise between each pair of their predecessors. The mandibles are weak, with rudimental palps. The last pair of legs are often turned directly backwards. There are two families. 1. Cermatiidæ—antennæ bristle-like, longer than the body; limbs long, especially the last pair; those of the first thoracic ring palp-like, with no end claw; stigmata in the middle line of the back, ex. Scutigera. 2. Scolopendridæ—antennæ subulate, shorter than the body; eyes never compound; stigmata lateral. The antennæ are polyarthrous, bristle-shaped in Lithobius, or fourteen- (Geophilus), seventeen- (Cryptops), nineteen- (Eucorybas), or 18–, 20-jointed (Scolopendra); the ocelli are usually four, and the body segments unequal (Scolopendra, &c.), or equal, as in the blind Cryptops and Geophilus. Heterostoma has large, sieve-like stigmata. Arthronomalus electricus is phosphorescent.

Order 3. Pauropoda (*Lubbock*)—minute ($\frac{1}{20}''$ long), white, with no tracheæ; ten somites sparsely setose; generative organs anterior; legs nine pairs, of which one is on the third, and two pair on each of the fourth, fifth, sixth, and seventh segments. The head has no foot jaws; the antennæ are five-jointed, bifid, with three long, many-jointed appendages; the larva is hexapodal; dorsal plates, like those of Chilopoda. This includes one genus. Found in decaying leaves in temperate climates.

CHAPTER XLVI.

CLASS 4.—INSECTA (*Latreille*).

ARTHROPODS segmented into head,* thorax, and abdomen; the first, like that of a myriopod, of six fused somites; the thorax consists of three, pro-, meso-, and meta-thorax, each of which bears a pair of legs; the abdomen is of 7–11, usually nine somites,† limbless in the adult. Respiration is tracheal. Life is usually limited to one period of sexual maturity, and development is generally attended with metamorphosis.

The adult integument is usually chitinous, with hairs, bristles, or scales (calcified in the larva of Stratiomys), often with unicellular glands opening into the cuticular pore-canals, or into hairs whose tips must be broken before the secretion is emptied, or into the intermetameric spaces. In some insects are clustered glands secreting wax. In Aphides and those Coccida that secrete wax-threads, they occupy large surface-areas. In bees these glands, opening by many ducts, masses of gland-cells, tracheæ, and a covering layer of fat, make up, on front of the ventral rings, the "wax-organ." Aphides have also surface honey-glands. Some dermal gland-cells are phosphorescent, and odoriferous glands are often seated at the bases of the limbs, or intermetamerically, or around the anus. The products of these are often emptied

* Some Coccina have the prothorax and head united.

† Eleven, the normal number, only present in Orthoptera. Two are most commonly aborted or indistinct. Of these, strictly, eight are abdominal and three post-abdominal.

as a sudden shower. Many larvæ have spinning glands, early or late in development, as gland pouches on the upper lip: these secrete threads, often around sticks or foreign bodies (Oiketicus). Some Hymenoptera have a caudal sting. The colors of insects are in the chitinous layer.

The head bears the compound eyes, between and in front of which is the *facies*, consisting of the interocular region, *frons*, and an anterior segment or *clypeus;* beneath the mouth is the *gula;* on each side are the *genæ;* behind the facies is the *occiput*, which joins the frons at the *vertex*, and is attached to the prothorax by the neck. The head may be received into an anterior notch in the thorax (*caput receptum*), or concealed by the thorax (*c. obtectum*), or free (*c. liberum*). The single pair of antennæ arise below the eyes, and may be clavate, capitate, dentate, pectinate, flabellate, geniculate, aristate, &c.; between these may be ocelli or single eyes. The head also carries the oral organs, which consist of an azygous upper lip (*labium*), movably jointed to the clypeus; laterally there are, first, a pair of biting mandibles, hinged, and moving like a pair of tongs, never palpiferous nor jointed; each has two condyles at base for articulation with the inner wall of the gena. Behind these are the maxillæ, usually more delicate than the former, and consisting of a transverse basis articulated to the gula (*cardo*); on this is placed a *stipes*, which, on a separate portion, or *squama*, bears a maxillary palp. Internal to the stipes projects the *mala* or *lamina*, often divided into external and internal. Still farther back are the second pair of maxillæ, rarely remaining separate, usually united mesially as a lower lip

(*labium*), sometimes palpiferous. The united cardines of this pair of maxillæ form the chin or *mentum*, in front of which a tongue or ligula may be formed by the union of *stipes*, *squama*, and *mala*. These parts may be modified in different ways as suctorial organs.

The dorsal surface of each segment of an insect's thorax is the *pro-*, *meso-*, or *meta-notum;* the under surface is the *pro-*, *meso-*, or *meta-sternum*, and the sides are called *pleuræ*, each of which is divided transversely into a fore (*scapula*) and hinder piece (*epimerum*). The mesonotum bears a somewhat triangular area (*scutellum*), with two lateral areas or *parapsides*. Endothoracic projections exist at the sutures. Mesially on the metanotum is the *post-scutellum*. Sometimes the thoracic segments are closely united, or the prothorax may be free (*prothorax liber*); in this case alone is it large. The legs articulate in cavities (*acetabula*) between the sternum and pleuræ. The first part of the leg is the *coxa*, more or less sunk in the acetabulum; next follows a ring or *trochanter* to articulate with the next joint, or *femur;* then follows the *tibia*, often with a movable projecting spur (*calcar*); and lastly the *tarsus*, of several joints, carrying at its end two, rarely one claw, and often dermal folds between (*pseudonychia*). Limbs may be natatory and flattened, gressorial, fossorial, saltatory, or raptorial.

Dorsally articulated are the wings arising between the notum and pleuræ of the meso- and meta-thorax; that on the first is the fore-wing, that on the second the hind-wing. These are flattened saccular elongations of the integument, whose inner walls coalesce, and are separated and supported by the *costæ* of the wing, consisting of branches of tracheæ with a thickened chitinous lining, and chitinized externally. In beetles, &c., the fore-wing becomes thickly chitinized, loses its flying power, and becomes an *elytron* or wing cover. Wings may be absent, especially in females.

Each abdominal ring is divided into separate large dorsal and small ventral, sometimes into lateral, pieces; thus the abdomen is distensible; posteriorly it often bears anal or genital appendages—bristles, spines, stings, forceps, vaginæ, cerci. The abdominal segments of the adult never carry limbs except in the beetle Spirachtha eurymedusa, whose third, fourth, and fifth segments bear two-jointed appendages.

The larvæ of Lepidoptera and many Hymenoptera bear small papillary processes, like the parapodia of worms, on the somites behind the thorax, but the three anterior pair alone exist in other larvæ, as in Myriopods, and these alone have adult successors. In the larvæ of Phryganea the thoracic limbs are utilized as assistants to the jaws. The wings are structures comparable with the shells of Entomostraca; their motions in flight are very rapid. The house-fly makes 300 strokes per second (*Marey*); the point of the wing describes a figure of 8. The muscles are striped, colorless or yellow, and complexly arranged.

The epipharyngeal nerve ganglion is large and lobed; the hypopharyngeal is joined to it by short, but to the first thoracic by much longer bands; the three thoracic ganglia may unite into one or two, and the ventral ganglia vary from six to four.

In parasitic insects the hypopharyngeal ganglion and the ventral cord become closely united. The brain ganglion is generally medially divided; in ants and bees it is singularly convoluted and lobed;* the antennary, optic, and commissural nerves arise from separate lobes. The ventral ganglia

* Probably these may be sensorial. *Faivre's* experiments indicate that co-ordination of motion may reside in the hypo-, and will in the epipharyngeal ganglia.

are originally pairs, but they early fuse; the longitudinal commissures, however, remain double. From the hypopharyngeal ganglion arise the oral nerves; from each thoracic ganglion the branches for the legs and wings of that somite; the abdominal ganglia are usually small, except the last, which sends branches to the outer reproductive organs. The nerve cord may extend for the whole length of the body, as in Orthoptera and Neuroptera, with 6–9 abdominal ganglia. In Hymenoptera there are only two thoracic ganglia and 1–3–4 or 6 abdominal. In Coleoptera there may be also not only two thoracic (the meso- and meta-thoracic being fused), but the abdominal ganglia may be united into one mass (Lamellicornes, Scarabæidæ, Melolonthidæ, Curculionidæ, or may be segmented into eight (Carabidæ, Lucanidæ, Cerambyces). Other families show intermediate conditions. In Thysanura the number of ganglia in the ventral chain is variable—twelve in Lepisma, three in Smynthurus. In some Hemiptera there is a single thoracic and a single abdominal ganglion. In Lepidoptera there is a union of the second and third thoracic ganglia in the adult, but they are often distinct in the larva; and of the first and second, and often third abdominal ganglia, which are also distinct in the larva. The last (fourth abdominal) ganglion is bilobate, and seems double. In all cases the commissures are not only laterally but antero-posteriorly double, and the ventral portion has been supposed to be sensitive, the dorsal to be motor, the latter passes over, and fuses only partially, or not at all, with the ganglia.* The nerves arise by two roots, one from each of these elements.

* The nerve cord is kept in its place by a muscular layer springing from the body wall, and passing transversely over the chain of ganglia, sometimes attached to the neurilemma of the interganglionic commissures (Orthoptera), or also free from it (Hymenoptera), or as a meshwork of irregular fibres, interlaced and inserted into the neurilemma (Diptera). In Lepidoptera the neurilemma thickens, and forms a solid cord between the longitudinal commissures, and into this connective axis the muscles are inserted.

Besides this nerve system there are three series of visceral nerves:—First, symmetrical, lateral, sympathetic nerves arising from the back of the brain ganglion, and running on the side of the œsophagus, forming one, two, or many ganglia thereon. Second, the *nervus recurrens*, a medial nerve, arising from a small triangular single, rarely double or triple (occasionally) *ganglion frontale*, anterior to the epipharyngeal ganglion (from each side of the front of which its roots, the nervi vagi, spring), passing backwards on the dorsal aspect of the œsophagus, to form a plexus with branches of the foregoing. Third, *nervi transversi*, arising from the upper cord of the ventral nerve chain; each of which divides into two branches in front of each ganglion, receives branches of communication from the foregoing, and supplies the tracheæ and the muscles of the stigmata. In development the nerve system is comparatively late in being differentiated from the tissues around it. The nerves terminate in distinct *Doyérean eminences* in muscles, often in *touch rods*, or hair-like free ends on the surface.

The antennæ are abundantly provided with touch corpuscles, which also exist on the palps and tarsi. Short conical bodies on the front of the antennæ may be organs of smell.* Hearing organs are not universal, but the antennary rods of graduated lengths have been shown to vibrate in response to certain musical sounds; some have a chitinous ring, over which is stretched a drum-like membrane; beneath this is a trachea dilated into a vesicle, on which is seated

* Or the fine pores on the antennæ of Lamellicornes (*Erichson*), or the stigmata? (*Cuvier*).

a ganglion whose nerves end in club-like rods, with fine acoustic hairs. This is placed under the knee on the outside of the front pair of legs in Crickets, or in a shallow depression on the metathorax, close to base of the third pair of limbs, and receiving its nerve from the third thoracic ganglion in Acrididæ. In Locusts it is placed on the front pair of legs, and there is an opening into its cavity. At the base of the *halteres* of Diptera and at the base of the hind wings of beetles there are areas where the chitinous integument is pierced abundantly by pore-canals, and beneath which are clusters of rod-like nerve endings, like those in other auditory organs, but with no tympanic ring nor membrane.*

Eyes are absent in cave-dwellers, or those living in dark places, but are usually two, compound, sessile, lateral, with sometimes accessory cornea-bearing ocelli, varying in number: this class of eyes, or none, exist in larvæ as a rule. The compound eyes consist of 20–, 50–, 4000 (House-fly), 28,000 (Dragon-fly), hexagonal, rarely quadrate facets. The organ is stalked in Chloeon, Diopsis (Dipteron), and some Strepsiptera and Hemiptera, but the stalks are not movable.

The muscles of insects are grouped into those with, and those without, prolongations from the exoskeleton (tendon) for their insertion; the first group are either conical, with a single, or pyramidal with a laminated tendon, penniform or compound (arising by several heads). In the larva of Cossus ligniperda there are 228 muscles in the head; 1647 in the body; and 2118 in the viscera; but these, which are little more than divided fasciculi of fibres, are capable

* *Hicks* and *Lespes* describe auditory (?) vessels in the antennæ of Lamellicornes.

of grouping into larger series.* There are retractors and occlusors of the spiracles, and numerous muscles for the limbs and wings, which nearly fill the entire thorax.

The pharynx has often lobate processes (*epi-* and *hypo-pharynx*) on its under surface, not to be confounded with outer movable processes of the tongue or *paraglossa*. The œsophagus is often dilated into a crop which may be a thin-walled and pedunculate,† lateral sucking stomach; double in Chrysis and Lepidoptera; the proventriculus, or gizzard crop, has muscular walls and chitinous teeth, absent in suctorial insects; the thin-walled stomach has no chitinous lining, but is glandular, often with cæca or villi within.

The small intestine, or *ileum*, which follows, ends in the rectum, at whose lower end are 4–6 longitudinal ridges, on which rectal glands open. The length of the intestine varies with the solidity as much as with the nature of the food; thus the vegetable-feeding suctorial Cicada has a long intestine, while the grasshopper has a much shorter one. In larvæ the gastric region is long, and the intestinal short, while in the adults these conditions are more than reversed, and the intestine generally becomes curled. The stomach may have cæca along its entire extent, or only at its origin (Orthoptera), two (Locusts and Crickets), six (Acrididæ), 4–8 (Perlidæ), none (Earwig and Phasma); the stomach itself may be long and convoluted, as in Melolontha, Bees, &c. The rectum generally dilates at its pre-anal end, and there

* Each wall of the caterpillar of the cabbage butterfly consists from within outward of—first, two layers of longitudinal; second, superficial and deep internal obliques; third, superficial and external obliques; fourth, a superficial rectus, fifth, another layer of oblique fibres; sixth, triangular diagonal fibres; seventh, transverse fibres in several layers.

† Where the duct of this sucking stomach joins the œsophagus there is a flat muscular sucking disc.

are many tracheæ on its papillary ridges, which in the aquatic larvæ of many dragon-flies are extended into tracheiferous lamellæ, named *tracheal gills*,* which by the opening and shutting of the anus are kept bathed with currents of water, and thus serve as respiratory organs. Some Hymenopterous and Pupiparous Dipterian larvæ have no anus, and in ant-lion larva the rectum, thus cut off from the stomach, becomes a spinning apparatus, with a fine outlet, and receives the Malpighian tubes. In the larvæ of Dyticus and Hemerobius, as well as in Myrmeleo, there is no mouth, but there is a large opening at the point of each of the powerful maxillæ leading by a canal into the œsophagus.

Salivary glands are usually present (absent or small in Ephemeridæ, Odonata, Scalidæ, Aphides, &c.) They are two long, lobed pouches in Termes; tortuous tubes in Beetles, Diptera, and Lepidoptera, or 1–3 pair of acinose glands in Hemiptera and Orthoptera. Panorpa has six large glands in the male, and only one minute pair in the female. The duct is dilated in Mantis, Lucilia, &c. Fine longitudinal or tortuous brown or whitish *Malpighian tubes* open into the intestine (except in Poduræ, Coccidæ, Aphis, and Chermes), but present in Lepisma and in most other insects. There are four in most Diptera and Hemiptera, six in Lepidoptera and Neuroptera, four or six in Beetles. They open close behind the stomach in Hymenoptera, Diptera, Cicadæ, Lepidoptera, &c. Larvæ have usually the same number of tubes as adults, except in Bees, whose larvæ have only four. They rarely branch, but sling-like unions between their ends are found in some, and sometimes vesicular

* Similar to these are the many-jointed *cerci anales* of many Beetles and Lepidoptera, which are possibly the representatives of the tail oars of Copepods.

dilatations. In many Hymenoptera they are numerous and short; in some Orthoptera over 100, and in Gryllotalpa, where they are numerous, they unite into a single duct. In Melolontha they open into a small cæcum: they contain uric acid, oxalic acid and leucin.

There is no liver: in some Hemiptera and Orthoptera cæcal tubes are described as pancreatic. The fatty body is large in larvæ, yellow, lobed, often fastened to the body wall and to the viscera which it suspends; around it are often netted tracheal branches. Its materials are used up in the pupa stages, and it diminishes as the sex-organs mature. In Lampyris it is modified into the luminous organ, which consists of a flat transparent lamella of polyhedric cells, richly supplied with tracheæ and nerves. On the dorsal side these rest on a layer of white opaque non-luminous cells, which contain concretions of urea. Probably the luminous organ in Elater is similar.

The blood is colorless, green, or red, with clear nucleated corpuscles and fat granules. The heart is dorsal, tubular, chambered, as in Myriapods, but lying in the abdomen, supported by triangular *ligamenta alaria*, or *musculi*, one attached to the outer connective coat of each chamber, and slung thereby to the body wall, and often to the neighbouring tracheæ; it is continued forwards, as the cephalic aorta, into the thorax and head. There are usually eight chambers, each of which receives blood through a pair of venous ostia guarded by valves, and sends its blood into the one before it, regurgitation being prevented by valves, until it reaches the aorta, from whence the blood returns by lacunæ to the heart. There is no

true pericardium for its collection. In the limbs definite blood channels are traceable, and in the wings true walled vessels and capillaries have been described.

The aorta is an anterior chamber of the heart, without venous ostia, or ligamenta alaria (*Weissman*). The heart muscle is not in discriminable strata. It acts more rapidly in the adult than in the immature stages. In Sigara coleoptrata there is an accessory contractile space in the tibia. The heart is a simple tube in some Dipteran and Hymenopteran larvæ.

Respiration is by various kinds of tracheæ. Some aquatic insects have a closed system, with no stigmata—a breathing organ differing from gills, in that the blood is aerated by oxygen separated from the water, and conveyed in tubes to the blood. The tubular system in the gill covers of Oniscus is closely related hereto. In Phryganea and some Dipteran larvæ there is a sub-dermal free branching of tubular or lacunary air channels, the dermis separating the air from the surrounding medium. A second breathing organ consists of leaf-like surface processes or areas containing these closed tracheæ (tracheal gills before referred to); these form a lateral row along the body of an Ephemeron larva and in other Pseudoneuroptera and Neuroptera, and persist in the Orthopteron, Pteronarcys regalis, which has thirteen pair. A third form of closed tracheæ is found in Dragon-flies, &c., where the internally placed tracheæ ramify on ridges within the rectum. Wings may be permanent, homologues of these external gills. Open tracheæ are most common, and they vary in number, and in the

arrangement of the stigmata, which may be two, sometimes tubular, posterior (in aquatic larvæ), or four (two in front on the second somite, as well as two behind, as in headless Dipteran larvæ), but usually they are more numerous. In adult insects they are in the soft intermetameric rings under cover of the wings. There is one pair in aquatic Hemiptera (Nepa). Smynthurus has one pair of stigmata on the head beneath the antennæ. Papirius has no tracheæ, nor has the larva of Chloeon for its first few stages before its tracheal gills develop. Podura has four pair of abdominal stigmata; others have even one on every postcephalic somite. The stigmata may have a raised border (Peritreme), valves, bristles or a sieve like cover (Œstrus larvæ, Lamellicornes). These tracheæ may be simple unbranched, or may have simple anastomosing tubular branches, or may have vesicular dilatations, with no spiral thread, as in some flying insects. The anastomoses may produce continuous longitudinal or transverse canals.

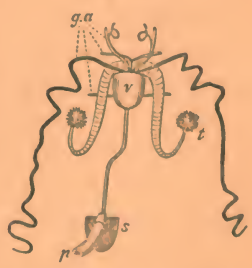
Many insects emit sounds which are audible to us, and probably many others produce notes too high for our appreciation. They may depend on the rubbing of the body rings together, the streaming of air from the stigmata, the rubbing of the wing covers against the back or the hind legs, or the head against a chitinous plate.

All insects are normally oviparous and diœcious, the sexes often differing conspicuously. The testes are two, rarely twelve, in a pair of clusters, as in some beetles, branched or pouch-like, united into one in some Lepidoptera, in a connective sheath (*tunica vaginalis*). From each passes a vas deferens, which

unites with its fellow in a common ejaculatory duct, to which are appended 1–3 pair of long, tortuous, or branched mucous glands for uniting the thread-like spermatozoa into spermaphores, and one or two *vesiculæ seminales*. There is often a chitinous, grooved, or tubular penis, which may lie in a special capsule (some beetles), and may be an elongation of the end of the duct. The sex orifices are usually in the space between the eighth and ninth ring, rarely far forward, as in the female Strepsipters. In Libellula, the penis is on the second abdominal segment, and has at its base a seminal vesicle, which, by a bending of the abdomen before copulation, is filled from the vas, which opens far back.

The female has a tubular ovary on each side (or a dense, often verticillate, bundle of ovarian pouches, as in Hydrobius, &c.), fixed by an ovarian ligament. The oviduct begins as a *calyx*, and opens into a common uterus, ending in a vagina, at whose mouth open one (Cicada) or two simple or branched colleterial glands, by whose secretion the eggs are united and fixed in their places. A *receptaculum seminis* opens into the vagina, or into the hinder part of the oviduct, and there is often a separate cæcal pouch from the vagina or *bursa copulatrix* for receiving the penis. Owing to these receptive cavities, one impregnation fertilizes successive broods of eggs. There are also chitinous organs whereby the eggs are laid,

Fig. 44.



Reproductive organs of Lytta. *g. a*, accessory glands; *t*, testes; *v*, vesicula seminalis; *p*, penis.

(*ovipositors*), in the forms of piercers or saws, &c. The ovipositor and penis are both altered metameres.

In the ovary arise two series of products. The terminal cells of the ovarian tubes produce the ova proper, but in the epithelial wall of the tube lower down is secreted a yelk mass for the nutrition of the germ.

Insects' eggs have an outer, often sculptured, shell, which has usually a micropyle at one pole. In some Diptera the eggs are retained and hatched in a cæcal process from the vagina. In Melophagus the colleterial glands secrete a fluid whereby the young are nourished in the larval stage.

True or pseudo-parthenogenesis (p. 36) occurs in many insects. Metagenesis has been described in Cecidomyia, where a larva produces embryos: but as there is a peculiar pseudovarum present, though with no oviduct, this is probably a form of pseudoparthenogenesis.

In the developing egg, after the partial (rarely complete, Poduridæ) fission of the yelk, a germinal membrane forms usually around the yelk, with a primitive ventral streak, in which the abdominal and head segments begin to appear. Eggs are thus usually ectoblastic, but some seem to have a periphery of yelk, and be endoblastic. The germ is inclosed in a cellular amnion (chitinoid, structureless in Poduridæ, *Packard*). Finally, the germ breaks the shell, sometimes by the help of provisional organs (Pentatoma, Phryganea, Mantispa). The young thus produced is a *larva*, and this may only differ from the perfect adult in size, and in the number of corneal facets, or else the larva may, by developing wings and a more

sharp differentiation of the thorax, assume its adult form. Insects which only undergo changes like these are called *ametabolous*. Other insects, while undergoing the growth of wings, &c., lose embryonic organs, and are called hemimetabolic. Most, however, differ very much in their larval and perfect states, and the former passes through a quiescent or *pupa* period before it becomes mature; these are holometabolic. The larvæ, or caterpillars in general, are annelid-like, nearly homonomous, with a soft skin, and stumpy or no feet; when present, the three anterior pair are often discriminable from the others (which are called prolegs*), in shape and colour, and in being several-jointed (often five). They are voracious, with powerful jaws, a large stomach, and a large fatty body; they grow rapidly, and moult frequently. On attaining their full size, those with labial silk-glands spin a *cocoon*; others become quiescent, inclosed in a thickened skin, and cease to eat. This *pupa* or *chrysalis* stage lasts until the internal organs attain perfect development. They seem to undergo a nearly perfect histolysis, and from certain areas of formative tissue, called *imaginal discs*, rearrangement takes place; then the pupa skin splits along the back, and the *imago* or perfect adult is produced. The pupa may be *free* when the locomotory organs remain free from the trunk, as in Hymenoptera and Coleoptera, or *obtected* when these organs are inclosed in the pupa skin, and so are covered, as in Lepidoptera, or *coarctate*, when the whole body is wrapped up, with no trace of limbs, as in Diptera. On becoming free,

* Prolegs may be seven pair (Tenthredo), or eight (Cimbrex).

the soft imago body speedily dries, and early discharges the urine which had been accumulating during the pupa-sleep.

Some larvæ have bristles, or, in Sphingidæ, a dorsal horn. The head bears a pair of *procephalic* scales or lobes, in front of which is a *proclypeus*. The larval antennæ differ from those of the imago, and joint with the front edge of the procephalic shield, external to the articulation of the mandible, thus resembling the antennæ proper of Crustacea, while the imago antennæ, arising farther inwards and forwards, are the homologues of the antennules (*Zaddach*). Some larvæ are dimorphic.

CHAPTER XLVII.

CLASS INSECTA.

INSECTS are almost all terrestrial; very few (Halobates, Gyrinus) are marine. About 175,000 species are known, which can be divided into two sub-classes, according to the extent of their metamorphoses.

Sub-class 1. Ametabolica—with no, or imperfect metamorphosis.

This includes the following six Orders :—

1. Mallophaga (*Nitzsch*)—wingless, flattened, ametabolic; parasitic on birds and mammals; antennæ 3–5 jointed; eyes simple; mouth masticatory; mandibles hook-like; palps four-jointed, or none; meso- and metathorax mostly fused abdomen 9–10 ringed, but with few (4–6) ganglia; pharynx muscular; intestine simple. The antennæ may be three- (Trichodectes) or five-jointed, thread-like, with no maxillary

palp (Philopterus), or clavate, four-jointed, with (Liotheum) or without a palp (Gyropus). This may be a sub-order of the next.

2. Rhynchota (*Fabricius*)—with or without wings; mouth suctorial; labium elongated into a long, apparently jointed, tube (*vagina*), only open above at the base, where it is covered by the opercular labrum. Within this the maxillæ and mandibles are altered into sharp, protrusible, piercing setæ; maxillary palps none; labial palps merged into the vagina; eyes moderate, compound or simple; the antennæ are either short, 2–3 jointed, and aristate, or long. When wings exist, the fore pair are often, for at least half their extent, leathery or horny, forming *hemielytræ* or sheaths for the hinder pair. The tarsus is usually 2–3 jointed; the stigmata are ventral; there is no crop; a long, often trifid, stomach; the intestine is usually tortuous, with four Malpighian tubes; there is no bursa copulatrix (except in Cicada, which has a double receptaculum seminis); the larvæ, at the first moult, show the rudiments of the wings; many of them have odorous glands on the metathorax or abdomen; they are mostly retrogressive forms, living on plant or animal juices, and include three sub-orders:—

1. Pediculina (*Burmeister*)—lice, wingless, ametabolic, with two ocelli and a sharp proboscis armed with recurved hooks; antennæ thread-like, five-jointed; thorax obscurely segmented (Pediculus); extremely small in Phthirius; parasites on mammalia. At least three species infest mankind:—Pediculus capitis, the head-louse; P. vestimenti, and P. tabescentium, the louse which multiplies so rapidly in the disease Phthiriasis, of which Herod, Sulla, Honorius (King of the Vandals), the Emperor Arnulf, Philip II., &c., died. Hæmatopinus is a common pig- and cattle-parasite.

2. Homoptera (*Latreille*)—wings two or four, equal, lying straight, and imbricated on each other when at rest; often absent in the females; mouth usually turned back; prothorax short, and the three thoracic rings more or less united; eyes compound, with ocelli between them. Here belong the following families:—1. Coccidæ—mostly tropical, phytophagous; antennæ six- or more jointed; proboscis, and often hind

wings, rudimental in the male; tarsus two-jointed (one-clawed in Dorthesia); females wingless, rounded, winged in Aleurodes, their bodies covered with eggs; the males have a pupa stage in a cocoon; Coccus cacti yields cochineal; C. lacca yields shellac; Porphyrophora yields German cochineal; C. ceriferus yields Pe-lac wax. 2. Aphididæ—antennæ five- (Chermes), six- (Rhizobius), or seven- (Aphis) jointed, often longer than the body; wings four, or none; tarsus two-jointed; salivary glands and Malpighian tubes none. Aphides, Lachnus, and Schizoneura have two glandular *cornula* or honey tubes at the end of the abdomen, the secretion of which is eagerly devoured by ants; ocelli none. Pseudoparthenogenesis occurs among these; the eggs hatched in spring, producing wingless, imperfect females, whose ovary produces germs with no germinal spot (*pseudova*), which develop without fertilization. This process goes on in successive broods until the altered condition of food and temperature at the incoming of autumn checks it, and this last brood consists of males and females with perfect sex-organs, whose fertilized eggs survive the winter to undergo the same round on the renewal of favourable outer conditions. Schizoneura lanigera, with a red, spotted abdomen, is a pest of fruit trees. 3. Psyllidæ—antennæ as long as (Psylla), or shorter than, the body (Livia); 8–10 jointed, with two fine terminal aristæ; ocelli three; femur thick; tarsus two-jointed, with lobes between the two proper claws; fore wings leathery. 4. Cicadellinidæ—head free; frons broad: ocelli two, or none (Typhlocyba, found on diseased potatoes); antennæ short, two-jointed, aristate; fore wings leathery; hind legs long. Aphrophora, with two sharp calcaria on its hind leg, secretes the "cuckoo-spit." Ledra has two upright, ear-like processes on the prothorax. 5. Membracidæ—head down-directed, with two ocelli between the eyes; prothorax with large processes, which often overhang the abdomen, and whose shapes are often eccentric, as stalked globules or ridges, &c.; mostly American, except Centrotus. 6. Fulgoridæ: Lantern-flies—head with vesicular or cornute processes; wings colored. F. laternaria is the lantern-fly of Guiana. Flata limbata produces Chinese

wax. 7. Cicadidæ—head short, vertical; eyes prominent; ocelli three; antennæ internal to the eyes, seven-jointed; a bursa copulatrix and two receptacula seminis; intestine 6–10 times as long as body; a drum-head-like elastic membrane lies on the under side of the first abdominal ring in the male, whose tension is altered by a muscle producing the characteristic shrill τεττιγωνια; behind this drum-head is a vesicular trachea.

Sub-order 3. Heteroptera (*Latreille*)—anterior wings hemielytræ, horny in front, membranous behind. The first four families are aquatic (Hydrocores), the others are terrestrial (Geocores). 1. Notonectidæ—back convex; venter flat; head large; antennæ four-jointed, hidden; ocelli none: hind legs flattened, natatory, bristled along their edge; anterior tarsus one- (Corixa, Sigara) or three-jointed (Notonecta). 2. Nepidæ, Water Scorpions—broad and flat; *caput receptum;* eyes large, and no ocelli; fore feet for grasping, hinder for swimming; stigmata with sieve-like opercula. In Ranatra there are large, thoracic, tracheal vesicles and largely developed tracheæ elsewhere. Nepa and Ranatra have also two tracheal tubes opening at the anus. 3. Galgulidæ—body discoidal; antennæ four-jointed; ocelli distinct. 4. Ploteres—body small, with no neck, silky haired below; antennæ long, four-jointed; middle and hind legs long, whereby they can leap on the surface of the water. Halobates inhabits the Pacific Ocean. Hydrometra has a large pro-, overlapping the meso-, thorax. 5. Reduviidæ—tropical; head free; antennæ thread-like, four-jointed; proboscis subulate, triarthrous; prothorax with transverse constrictions. Conorhinus sometimes sucks human blood. 6. Membranacei—flat, usually wingless, with four-jointed antennæ, three-jointed vagina, and two-jointed tarsus. Cimex, the bed bug (introduced into England in the sixteenth century), has no ocelli. Aradus has wings. 7. Capsidæ—head small, recept, trigonal; ocelli none; eyes small; vagina four-jointed; tarsi unequal, three-jointed; hemielytra with an appendage in front of the membranous part. 8. Corisidæ—head flattened, deeply recept; ocelli two; antennæ thread-like, often highly coloured; wings membranous, often with forked veins;

mostly tropical. Anisoscelis has dilated tibiæ: some have remarkable forms.

Order 3. Thysanura (*Latreille*)—wingless, ametabolous, living in damp, dark places, hair- or scale-clad, rarely with compound eyes, but with two groups of 6–14 ocelli; mouth masticatory; Malpighian tubes few, long; abdomen with terminal bristles or a bifid tail. Lepisma has the typical lower lip of Orthoptera; others have no trace of a second maxilla, as in Myriopods. They include two families:—1. Poduridæ—cylindrical mouth, small, with no palp; abdomen 6–3 ringed, with a fork-like tail, whereby they can spring; hairy or scaly back; prothorax small, hidden; ocelli four (Achorutes), seven (Desoria), or eight. Cyphoderus has a cup-like mesothorax. Podura scales, being finely lined, are used as test objects for the microscope. Smynthurus has cephalic stigmata. 2. Lepismidæ—fusiform, with small metallic scales and many-jointed antennæ; abdomen ten-ringed, with five end-bristles, of which the middle is the largest. Machilis (Petrobius) has compound eyes. Nicoletia is blind. Lepisma, the scales of which are also commonly used as microscope tests, lives in sugar.

Order 4. Thysanoptera (*Haliday*)—small, flattened, found in vegetables; head cylindrical; mouth suctorial, directed downwards and backwards; maxillæ fused with the labrum; mandibles bristle-like; antennæ 8–9 jointed; eyes large; ocelli present; maxillary palp 2–3 jointed; labial two-jointed; prothorax small; wings two pair, equally long, bristled, not folded, with few veins; rarely short or none. Tarsi two-jointed, with a sucking disk and no claws; intestine about twice as long as the body; malpighian tubes four, free at the tips. The females of Thrips have a compressed four-valved ovipositor. Phlœothrips has a tubular last abdominal segment in both sexes.

Order 5. Euplexoptera (*Westwood*): Earwigs—head free; clypeus short; labrum large, crescentic; labium cleft to the base of its stipites; ocelli none; eyes over the thread-like 12–40 jointed antennæ; prothorax quadrangular; hemielytræ much shorter than the abdomen, with no membranous area; hinder wings thin, fan-like, with radial costæ, useless for

flight; tarsus three-jointed; abdomen nine-ringed; the seventh and eighth are short in the female, and covered by the sixth; posteriorly is a forceps of two incurved processes on both sexes. The female incubates her eggs.

Order 6. Orthoptera (*Ray*)—hemimetabolic, with no pupa stage; wings four, with reticulated costæ; when they are unequal, the fore pair is small, pergamentaceous; the hinder membranous, broad and longitudinally folded; mouth masticatory; mandible toothed; maxilla overhung by a helmet-like, outer lamella (*galea*), with 5–7-jointed palps; labium completely cleft, its palps three-jointed; the eyes are large, and there are usually 2–3 ocelli and many-jointed antennæ; the salivary glands have a receptaculum and 6–9 glandular pouches opening into the stomach. There are many short Malpighian tubes, and the ventral nerve cord is sometimes curved, and longer than the sessile abdomen. Some have no bursa copulatrix, but often a two-valved *oviscapt* formed of the modified last abdominal rings; larvæ apterous, but wings appear at the fourth moult; tracheal gills or *cerci anales* are often present. This polymorphic group includes the following sections and families:—§ 1. Cursoria—running forms, including: 1. Blattidæ—flat, oval; head covered by the prothorax; antennæ bristle-like; tibiæ spiny; tarsus five-jointed; wing covers overlapping medially; abdomen with 9–10 dorsal, and six (female) or eight (male) ventral rings. In Polyzosteria both sexes, in Heterogamia and Perisphæria the females alone, are apterous. All but Blabera have a lobe between the tarsal claws. Periplaneta orientalis is the common cockroach.

§ 2. Gressoria, walkers. 2. Phasmidæ—body linear, rod-like, with all the legs equal, and often lobate dilatations of the femur and tibia; tarsus five-jointed, with an accessory claw between the two normal claws; eyes semicircular; upper lip deeply notched; mesothorax elongated; tropical, walking-stick insects. In Bacteria and Bacillus both sexes are wingless. The male alone has wings in Cladoxenus, and both in Phasma, Prisopus, and the leaf insect Phyllium. 3. Mantidæ—head free, vertical; thorax and abdomen elongate; wings large; front legs flattened, sharp, raptorial. Schizocephala

has its prothorax three times the length of the meso- and meta-thorax.

§ 3. Saltatoria, leapers—female with an ovipositor (except in Gryllotalpa); mostly winged. 4. Gryllidæ—cylindrical, with thick, free head, elliptic eyes; bristle-like antennæ; maxillary palp with a vesicular point; fore wing horizontal; hinder larger, closely folded; hind leg long, thick; fore limbs are for burrowing in Gryllotalpa, or simple, gressorial, and the prothorax smaller, as in Gryllus. Acheta, the house cricket, belongs here. Platyblemma has a wide forehead. 5. Locustidæ—wings, when in rest, imbricated; body long, laterally compressed; antennæ bristle-like; the males have a sound-apparatus in the right elytron; the hind legs are long, with thick thighs. Schizodactylus has the wings elongated, and spirally twisted behind. Here is included Decticus, the grasshopper. 6. Acrididæ—head vertical; body laterally compressed; elytræ small, with no sound-organs; tarsi three-jointed; forehead with a longitudinal keel. Œdipoda migratoria is the destructive locust.

§ 4. Corrodentia—wings homonomous, not capable of folding together; tarsi 2–3 jointed; end segment of the lower lip of two lobes. 7. Embidæ—head longitudinal, free, four-angled, with small eyes; ocelli none; prothorax narrow in front; tarsus three-jointed. The larvæ spin cocoons in these tropical forms. 8. Psocidæ—head large, with a vesicular forehead; long bristle-like, 8–10 jointed antennæ; no maxillary palps; wings, when present, unequal, the hinder being one-half the size of the fore. Troctes pulsatorius is the book-louse or death watch.

§ 5. Socialia—besides the winged sexual individuals, there are apterous, sexless forms. 9. Termitidæ (white ants)—head free; antennæ short; rosette-like; 13–20 jointed; ocelli three; outer maxillary lamina leaf-like; tarsus four-jointed; males and females with delicate wings, apterous workers, with small round head, and small mandibles, and soldiers, with large square head, and sting mandibles, exist in the colony. In impregnated females the abdomen is very large. They build large hills of clay, cemented by their saliva, within which are regular galleries.

§ 6. Amphibioticæ—with aquatic larvæ. 10. Perlidæ—body long, flat, with bristle-like antennæ, lateral eyes, equal thorax rings, large hind wings, and a ten-ringed abdomen; aquatic larva has hypo-thoracic tracheal gills, which are retained during life by Pteronarcys. 11. Ephemeridæ—delicate, soft-skinned; eyes large in the males, small in the females; mouth rudimental; mesothorax long; fore wing large, triangular; hind wing small, or none (Cœnis). After the last moult it only lives a few hours; but the larva, which has strong jaws, and large lateral gills, lives 1–2 years in water. 12. Libellulidæ (Dragon-flies)—body long; wings delicate, equal, large, netted; jaws large, covered by the large upper lip; prothorax small; abdomen 9–11-ringed; larvæ with external (Agrion, &c.) or intestinal gills, and an elongated tongs-like labium (*mask*), which may be joined to the other parts of the head.

CHAPTER XLVIII.

SUB-CLASS 2.—HOLOMELABOLA.

INSECTS with full metamorphosis, and a pupa stage: herein are included eight orders.

Order 7. Neuroptera—prothorax free; tarsus five-jointed; mouth masticatory, with cleft labium, bearing a three-jointed palp; wings membranous, equal, the hinder never folded; body long; head short; eyes rarely very large; antennæ many-jointed, thread-like, convoluted (Panorpa); suctorial stomach rarely absent (ibid.); ovarian cæca numerous, verticillate, or pectinate; pupa free; larvæ carnivorous. The families are:—1. Megaloptera—antennæ club-shaped; head vertical, ligula undivided; larvæ with large heads, and sucking claws; including Myrmeleon or Ant-lion, whose larva lives in funnel-like sand-burrows, sucking whatever falls therein.

2. Hemerobiidæ—antennæ like strings of pearls; ocelli none; larva without suctorial claws; ligula strong, undivided; Chrysopa perla, the aphis-lion, emits a pungent odour. The larvæ of Sisyra live in Spongilla fluviatilis. Hemerobius has the last joint of the palp very long. Mantispa has the fore-limbs predatory. 3. Sialidæ—head flat, horizontal; ocelli present (none in Sialis); labium with a membranous, mesially-slit ligula, with terminal palp. Raphidia is called the camel-neck fly from the shape of its prothorax. 4. Panorpidæ, Scorpion-flies—head vertical, beak-like, with the clypeus at its extremity over the oval labrum, and a smaller bidentate mandible.

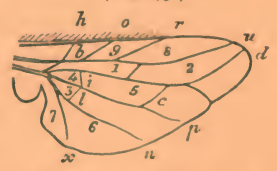
Order 8. Trichoptera (*Kirby*)—resembling the last, but with hair-clad or scaly unequal wings, of which the hinder pair are folded; mandibles membranous; maxilla and lower lip united into a valve-like flap, the palpi being nearly obsolete, or 2–5 jointed. The prothorax is reduced to a collar, and the meso- is longer than meta-thorax. This includes one family, Phryganeidæ or Caddis-flies, whose larvæ by agglutinating sticks, &c., make a case for themselves (spiral in Mormonia). The males and females often differ in the number of joints in their maxillary palp.

Order 9. Strepsiptera (*Kirby*)—minute viviparous insects; parasitic on the abdomen of bees and wasps. The males have four wings, the anterior short and twisted; the hinder large, fan-like infolding, and membranous, but with trifling power of flight; head short, vertical; eye large, with few facets; antennæ 4–6 jointed; legs clawless, with a four-, three-, or two-jointed tarsus. Females wingless, with a cephalothorax, and a worm-like abdomen; mandibles as two long, crossing bristles; maxilla fused to the labium, with a large two-jointed palp; labial palp none; pro- and meso-thorax short; metathorax very large. The larvæ have at first six long legs, two tail bristles, and tracheal gills. They live on wasp-larvæ, and at their first moult their limbs are lost, and they become worm-like, then attain their pupa stage, and the female never leaves her pupa skin. The eggs are developed scattered in the whole body. The eyes are stalked in Stylops, sessile, fifteen-jointed in Elenchus.

Order 10. Aphaniptera (*Kirby*): Fleas—laterally compressed, wingless, or with scale-like rudiments, with simple or no eyes, short antennæ, lying in a groove; labrum none; mandibles long, slender, saw-like, having between them the needle-like epipharynx. Maxillæ short, broad, with long, four-jointed palps; labium cleft, palp-like, often jointed; thoracic segments homonomous, discrete; hind legs saltatory; larvæ white, hairy, footless, worm-like. Blood-sucking parasites, closely related to Diptera, forming one family Pulicidæ. The labium is distinct (Pulex), or rudimental (Sarcopsylla, the chigoe; its females burrow in the skin of exposed parts in the West Indies).

Order 11. Diptera—metabolic, with suctorial mouths, two transparent, mesothoracic wings, with radiate costæ, and rudimental, often irregular, mesothoracic wings, modified into scale-like or pin-like *halteres*, or balancers; eyes two, very large; ocelli three, vertical; neck slender. The mouth is a proboscis, of which the labrum and labium each make make half-tubes;* the maxillæ (*scalpella*), mandibles (*cultelli*), are bristle-like, or knife-like, accessory organs, and the former always bear palps. There is also in the last a median sharp epipharynx (*glossarium*). The labial palps are absent, but the maxillary palps often appear as labial (Stratiomyidæ, Muscidæ). The antennæ are single, pectinate, or short, three-jointed, with a bristle (*arista*) at the tip, which may be naked (*arista nuda*), or hair-clad (*pilosa*), or terminal (*apicalis*), or dorsal (*dorsalis*). The prothorax fused with the strong mesothorax. The wing is divided by its costæ into celluli (Fig. 45), and at its base has two lobes, an *alula* and a *squama*, the latter over the *halteres*; the foot ends in two claws, with one or more intervening cushions or pulvilli,

(Fig. 45.)



Plan of Wing of Dipteron: 1, Anterior basal cell; 2, hinder marginal cell; 3, third basal cell; 4, second basal cell; 5, discoidal cell; 6, axillary cell; 7, lobe cell; 8, sub-marginal cell, *Loew*; 9, sub-costal cell; *Schiner*; *b*, mediastinal cell; *h*, humeral costa; *r*, radial costa; *o*, first longitudinal costa; *u*, cubital costa; *d*, discoidal costa; *i*, *l*, uniting costæ; *p*, postical costa; *n*, anal costa; *x*, axillary costa.

* That of the labrum = *valvula*, of the labium = *vagina*, with often a terminal lip, *capitulum*.

covered with sucking hairs, whereby they can walk on glass, &c. They have a stalked suctorial stomach, four or five often uniting Malpighian tubes, no bursa copulatrix, often three receptacula seminis, and a footless larva; some are viviparous; Miastor is said to be metagenetic, Chironomus is parthenogenetic. The aquatic larvæ have tracheal gills, and some have long breathing tubes. They are divisible into two series.

Sub-order 1. Pupipara—viviparous, the larvæ born when ready to become pupæ. The thoracic rings fused; labium unjointed, antennæ short, with a small knob, or two joints, often parasitic, unwinged; the abdominal ganglia are fused into one, intestine long. The families are:—2. Braulidæ or Bee-lice—wingless, with large eyeless heads, two-jointed antennæ, and five-ringed abdomen; claws comb-like; 2. Nycteribiidæ, Bat-flies—horny, with compressed, wingless, or abortively winged, head cup-like; halteres with a terminal knob; claws two-toothed; base of the second pair of legs with two comb-like organs; 3. Hippoboscidæ—spider-like, horny, flat-bodied, with large eyes; halteres free, small; eggs few, hatched singly, and the young nourished by sucking the secretion of the colleterial glands. Hippobosca, the horse-fly, has no ocelli. Sternopteryx is found on young swallows, Raymondia on bats, Melophagus on sheep.

Sub-order 2. Ovipara—the female lays eggs, or larvæ just emitted from the egg. These form two sections:—§ 1. Coarctatæ. The pupæ form within the larval integument, which hardens into a pupa shell. The families included are:—1. Stratiomyidæ—antennæ three-jointed; proboscis with a terminal fleshy lip; larvæ often with radiant cerci anales; heads often spiny, abdomen 7–8 (Xylophaga, &c.), or five-ringed (Stratiomys, &c.) 2. Syrphidæ—antennæ three-jointed, with single end joint, proboscis as last; fourth costa of wing simple, not forked as in last. 3. Conopidæ—head with large eyes, thread-like proboscis; halteres free; wings long; parasitic on other insects, Myopa and Conops on bats. 4. Muscidæ flies—antennæ three-jointed, with an end bristle; larvæ soft, with two protrusible lips; two horny jaws; ocelli distinct; proboscis with a fleshy end-lip; palps one-jointed; abdomen five-ringed—a very numerous family. One species of Tachina

is parasitic on earwigs. Sarcophaga carnaria is the flesh-fly; M. domestica, the house-fly; Calliphora vomitoria, the blow-fly, Lucilia Cæsar, the gold-fly, with glistening emerald green wings; Glossina morsitans, the Tsetze of Africa; Anthomyia and Scatophaga are the dung-flies. About 8000 species of flies are known. 5. Œstridæ, Gadflies: bots—antennæ short, wart-like, with a naked arista; proboscis rudimental; larvæ with recurved hooks on the edges of their wings. The eggs of Gastrophilus equi, laid on horses, &c., are licked by them, and develop in the digestive canal. Hypoderma, the deer and ox bot, has no larval hooks.

§ Obtectæ—pupa inclosed in a separate case, like that of Lepidoptera. These form two sub-sections:—1. Brachycera, with short antennæ, not more than three-jointed, of which, however, the last may be complex. This includes two groups, one with the proboscis short, the other (Brachystomata); the other with it long (Tanystomata). The former includes five families:—1. Scenopinidæ: Window-flies—abdomen flat; maxillæ rudimental; larvæ thread-like. 2. Platypezidæ—legs short; pulvilli two; found in mushrooms. 3. Dolichopodidæ—long-legged; pulvilli three. 4. Leptidæ—maxilla and epipharynx free; larva with two anal breathing tubes. 5. Therevidæ—tarsus with two pulvilli; pupa spiny. Group 2. Tanystomata—1. Asilidæ—elongated; head appendaged. The united mandibles and epipharynx form a piercer; maxilla sharp; labium pointed; tarsus with two pulvilli. 2. Empidæ—head small; proboscis variable in length, when long turned downwards, and with no terminal valve; piercing organ as in the last, but finer; abdomen eight-ringed; halteres uncovered. 3. Bombiliidæ—antennæ long, three-jointed, sometimes far apart; eyes large, connivent in the males; proboscis sometimes as long as the body, with bristle-like piercers; abdomen often woolly, 6–7-ringed; larvæ parasitic on other insects, in whose nests they live; pupæ with hook-like bristles. Bombylius is like a bee. Nemestrina has a proboscis four times the length of the body. 4. Tabanidæ—antennæ with three joints, annulated, often divided; eyes often bright coloured; mandibles present only in the blood-sucking females; the half tubular

labrum and epipharynx act as sucking organs. Hadrus pierces the human skin deeply (Brazil). 5. Inflata—head bent down, small, entirely occupied by the eyes; thorax and six-ringed abdomen large inflated; proboscis variable, sometimes longer than the body, and turned under the thorax, or absent; palps rudimental.

Sub-section 2. Nematocera—antennæ six-, or more-jointed. This includes two families:—6. Culicidæ: Gnats—proboscis long, thread-like; mandibles and maxilla free. The females alone sting, and the irritating fluid supposed to be instilled is the saliva. The pupa can move, and has thoracic breathing tubes; the larva has an anal air tube. 7. Tipulidæ: Crane-flies—proboscis short, fleshy; maxillæ fused with the labium, often also with the labrum; antennæ often plumose in males; wings usually long and small; the larva of Corethra has thread-like anal gills, four dorsal gill vesicles on the back, and no fatty bodies. Ctenophora has in the male comb-like teeth on the antennæ. Tipula has very long legs. The larvæ of Sciara sometimes wander in quantities in damp ground, following each other in chains. Cecidomyia cereale is the Hessian fly, which destroys grain. Heteropeza (Miastor) is the form in which Metagenesis is described. The larva of Ptychoptera has a long cephalic breathing tube.

Order 12. Lepidoptera—wings four, covered with small, coloured, imbricated scales; mouth suctorial; thoracic rings united; maxillæ united, elongated as a spiral *antlia* or suctorial tube, spirally rolled when not in use. The labrum and mandibles are aborted, and the labium is modified. The antenna is many jointed, club-like, filiform, or pectinate; eyes large; ocelli two or none. The maxillary palp is short, two-jointed, but the labial is always large. The prothorax is collar-like; the wings are radially veined. They have a sucking stomach, a convoluted intestine; six malpighian tubes, three of which may open together. The ovaria are usually four tubes, with a receptaculum, and a large bursa copulatrix. The larvæ are coloured, often hairy, with 5–6 ocelli on each side, and prolegs behind the six anterior. There are never prolegs on the first, second, seventh, or eighth abdominal segments, so there may be only 5–7 pair. The pupæ are obtected; but

the angular chrysalis case is marked with surface lines, isolating areas called *Opthalmo-*, *Ptero-*, *Podo-*, and *Cerato-thecæ*. The surface scales have a short, easily broken pedicle of attachment. A natural classification of the Lepidoptera is a desideratum; but they are often grouped, according to size, into Micro-, and Macro- lepidoptera. The former are minute, with bristle-like antennæ, often pectinate in the males, diurnal or nocturnal, with naked or sparsely-haired cocoon-spinning larvæ, with 4–5, rarely three, pair of prolegs. Another method of division is into Rhopalocera, or those with the antennæ club-like, and Heterocera, with variable antennæ. The families are:—1. Pterophoridæ—legs long; wing slit into feather-like plumes; larvæ with five pair of prolegs. 2. Tineidæ—labial palps long, scaly; maxillary often long, many-jointed, very often linear, pointed, or fringed; larvæ tubicolous; live on buds and branches (Lithocolletis). Tinea pellionella (clothes moth) and sarcitella live in woollen fabrics; T. uvella in grapes; T. granella in corn. The females of some are wingless. 3. Tortricinidæ—proboscis short; larva with five pair of prolegs, living in rolled up leaves. 4. Pyralidæ—with large labial and maxillary palps; hinder wing with, at its border, a bristled *retinaculum*. The Macro-lepidoptera have large broad, or long narrow wings, and are nocturnal, crepuscular, and diurnal forms. The nocturnal have the wings expanded, one colour predominating; when at rest roof-like, or rolled in to the body; larvæ with 2–5 pairs of prolegs. 5. Phalænidæ—ocelli none; body slender; antennæ bristle-like, or pectinate; proboscis small; wings delicate, with a retinaculum, caterpillars with 2–3 pair of prolegs. The larva of Apterus betularius, causes the tufts on birch trees. 6. Noctuidæ—body short, thick, conical; proboscis long, and palps large; fore-wing small, with two distinct spots; hinder joined to fore by a retinaculum; tibia spurred; larvæ usually naked. There are three types:—1. Geometriformes often diurnal, with broad wings; larvæ with rudimental abdominal feet. 2. Noctuinæ with naked larvæ. Trachea piniperda destroys pine trees. 3. Bombyciformes—with hairy caterpillars. 7. Bombycidæ—body thick, woolly; antennæ shortly pectinate; proboscis weak; wings sometimes absent (Psyche), or

abortive (Orgyia) in the females; caterpillars with five pair of prolegs, naked or hairy. Those with no retinaculum are Saturnia, Bombyx, the silk-worm moth, &c.; those with a retinaculum are Psyche, the female of which lives in a spirally coiled caddis-like case, &c. Allied hereto are the Cossi, wood-borers, with no ocelli; wings closely scaly, the front one much the larger; and Hepialus, with equal long-pointed wings; found on the root of the hops. There are two families of Crepuscular Lepidoptera. 8. Chelonaridæ—antennæ clavate, often pectinate in males; proboscis spiral; wings small, the foremost often spotted, with a retinaculum; ocelli rarely absent (Glaucopis). 9. Sphingidæ—antennæ prismatic, three-angled, thin at the point; body fusiform, often brightly coloured; fore-wing large, triangular, hinder short; larvæ with five pair of prolegs, smooth, with a horn above the anus. Macroglossa is truly diurnal. Acherontia, the death's head moth, is so called from the skull-like figure on the back. The diurnal forms are rhopalocerous—having hairy, clavate antennæ; they have no ocelli; large wings, brightly coloured on both sides, vertically folded on the back when at rest; the larvæ are often spiny; the pupæ are flat, angular, with no cocoon. The families are: 10. Hesperidæ—larvæ in rolled up leaves; imago small; thick-headed; with two pair of spurs on the hind leg; wings small and thin. 11. Papilionidæ: Butterflies—wings large, hard, usually of equal breadth, and with no retinaculum. This large family has been divided into two groups: 1. Succincta—pupæ with the head directed upwards, surrounded by a sling: this includes—§ 1. Equites—hind-wing usually tailed; fore-wing with four costæ on the inner side of the discoidal space. The females of Parnassius have at the distal end a pouch, formed of the hardened cases of adherent spermaphores. § 2. Pierines—fore-wing with three longitudinal costæ; hind-wing not tailed. Ageronia has rudimental fore-legs. Group 2. Suspensæ—pupæ suspended by a thread, with the head downwards. § 3. Danainæ—fore-legs rudimental; palp divergent, short. § 4. Heliconinæ—fore-legs rudimental; palp longer than head, divergent. § 5. Acræinæ—fore-legs perfect: palp divergent. § 6. Nymphalinæ—fore-limbs rudi-

mental, with fringed tarsus; palp large; both wings broad. § 7. Morphinæ—fore-leg small, not fringed; palp small; wings broad. § 8. Satyrinæ—fore-leg small; antennæ delicate; palps closely approximated; wings ocellated. § 9. Libytheinæ—palp as long as, or longer than thorax, thick, straight; fore-limb small in male, perfect in female. § 10. Erycininæ—palp small, with naked end-joint; fore-leg pefect. § 11. Lycæninæ — fore-leg small; palps long; caterpillars flat, short and broad; eyes of imago, hairy (Thecla), or naked.

Order 13. Coleoptera: Metabolous—four-winged, with a free large prothorax; and the anterior pair of wings (elytræ) hard, fully chitinized, and covering the succeeding pair; head mostly recept, with two compound, and rarely any simple, eyes; antennæ variable, 6–30 jointed; mandibles chitinous; maxillæ often leathery, with an aborted inner lamella; maxillary palp four-jointed; labial three-jointed; ligula undivided; mentum overlaps the labrum proper; mesothorax weak, with a scutellum, and bearing the elytræ; metathorax strong, bearing the functional wings. The elytræ have three margins; the inner is usually straight (except in Meloë, &c.) Where they touch medio-dorsally they form a suture, along which they may be adherent, when the hind pair of wings are functionless (*elytræ connata*). The hinder edge may form an apex, or may be shortened (*e. breviata*), so as not to cover the posterior abdominal rings, when they are called *e. truncata;* when their inner edges do not touch they are *e. dehiscentia*, or, if they overlap, *e. complicantia*. The hind-wing has its costæ mostly longitudinal, and it is folded longitudinally, and once or twice transversely, so as to lie when at rest completely under the elytron. The costæ often disappear in the wings of small species. The legs are gressorial or cursorial, rarely swimming, and more rarely leaping. The intestine is tortuous in the vegetable feeders, shorter, but more differentiated, in carnivorous forms. The penis is long, horny, covered with a sheath, and retractile. The Malpighian tubes are four short, or six long. The nerve-chain consists of three thoracic, and four or five abdominal ganglia, which may be more or less fused. The ovaries are fascicular tubes. A

few (Staphylinidæ) are viviparous; the larvæ are usually naked, hexapod, or footless, rarely with ocelli; the pupæ are *exsertæ*. A few larvæ (Meloë, Rhipidius, Metoecus, Lytta), are parasites. In Sitaris and Meloë there is a doubled larval stage. About 83,000 species are known, of which 10,000 are European.

They are divisible into the following Sub-orders:—

Sub-order 1. Cryptotetramera—mostly with a four-jointed tarsus, the penultimate joint being small. This includes four families:—1. Endomychidæ—head long; abdomen 5–6-ringed; larvæ living in fungi. 2. Coccinellidæ: Lady Birds—head short; body short, convex; flat beneath; antennæ short, eleven-jointed. 3. Pselaphidæ—elytræ only covering part of the abdomen. 4. Trichopterygidæ—antennæ eleven-jointed, thread-like; wings with long marginal hairs.

Sub-order 2. Crypto-pentamera—tarsi five-jointed, but the penultimate joint very small. 5. Bruchidæ—head long, with a thick neck; abdomen with five ventral rings; often found in leguminous pods. 6. Curculionidæ—head prolonged into a proboscis; œsophagus long; jaws at the tip of the snout; antennæ arising in lateral grooves; meso- and metathoracic ganglia fused. About 10,000 species are described. 7. Bostrichidæ—body small; head thick, short; mandibles projecting; palps small; eyes elongate, lateral; antennæ with swollen ends. The larvæ destroy the wood and bark of trees in which they burrow. Hylurgus and Hylesinus thus destroy the tips of the branches of pine trees. Scolytus and Tomicus are also destructive, the former especially to elms. 8. Longicornes (Cerambycidæ)—body elongated; head prominent; antennæ as long as, or longer than the body, usually eleven-jointed; mandible large, usually with a single point. 9. Chrysomelidæ: Gold Beetles—eyes lateral; antennæ moderate, thread-like, usually eleven-jointed; mandible with a forked point; larvæ with long legs, and ocelli. Some collect their excreta in their back, or form it into a shell, which they drag along. 10. Erotylidæ—like the last, but with a flat, 3–4-jointed club at the end of the eleven-jointed antennæ.

Sub-order 3.—Heteromera—pro- and mesothoracic limbs,

with five-jointed tarsi; metathoracic limb, with four large tarsal joints. This contains: 11. Tenebrionidæ—often wingless; mandibles short, strong; antennæ 10–11-jointed; elytra often connate; many have an ammoniacal smell, or are coated over with a sort of surface secretion; Blaps, the churchyard-beetle, Tenebrio, the meal-worm, often found in ships' biscuits, belong here. 12. Lagriariæ—antennæ eleven-jointed, free, pre-ocular; palps larger than the head; prothorax twice as long as the mesothorax; larvæ hairy, with four ocelli on each side. 13. Salpingidæ—head horizontal, free, not narrowed at base; antennæ clubbed at end; otherwise as last; larvæ with horny plates on each segment, and five pair of ocelli. 14. Pyrochroidæ—antennæ thread-like, or pectinate (Pyrochroa); head recept; larvæ with enormous penultimate segment, and two pair of ocelli. 15. Melandryadæ—antennæ pre-ocular, thread-like, maxillary palp with large end segment; larvæ with five pair of ocelli; living in dead wood. 16. Mordellidæ—body long, wedge-shaped; head vertical; maxillary palp with a knife-like terminal joint; mandible with a membranous margin internally; eggs large, oval. 17. Rhipiphoridæ—palps with single joints; mandible with no membranous margin; antennæ serrated in females, pectinated often in males. The larvæ of Metoecus paradoxus live in wasps' nests, that of Rhipidius blattarum in the abdomen of Blatta. 18. Cantharididæ—antennæ 8-11-jointed; head and neck smaller than the soft, leathery elytræ. The body secretes a pungent blistering substance (Cantharidine). In some forms the eggs are deposited in the nests of bees, and emit hexapod bristled larvæ, which are endoparasite. This larva moults, becomes free, then pupiform, emits a second larvæ of different shape, from which the pupa, and finally the imago, arise. This is called Hypermetamorphosis (*Fabre*). Cantharis, the Spanish fly, or blistering beetle, belongs here. Sitaris is in its larval stage parasitic in Anthophora pilipes. Meloë, the oil beetle, has rudimental wings. 19. Œdemeridæ—longicorn-like, with heteromerous tarsus, and a softer surface clothing; larvæ hairy, warted.

Sub-order 4: Pentamera—tarsi of all limbs five-jointed. This includes: 20. Carabidæ—body long, convex, hard,

often metallic in lustre; antennæ thread-like, eleven-jointed; mandible sharply curved; intestine with two anal glands, whose secretions contain butyric acid. Brachinus crepitans, the bombardier beetle, expels this forcibly, together with air, when disturbed. The elytræ are sometimes connate. Anophthalmus, a cavern form, is blind. The larvæ are long, sometimes hairy. Procerus includes the largest known species. 21. Cicindelidæ—slender, often lively-coloured, spotted, or bald; head broader than neck; maxillary palps with terminal hooks; larvæ linear, with broad head and prothorax; often with the eighth ring broader and higher than the others, and with two fleshy dorsal processes. 22. Amphizoidæ—hairy; the fore-limbs gressorial; the costæ of the hind-limbs approximated, flattened, as in the next family; outer edge of the maxilla with an unjointed process. 23. Dyticidæ—flat, aquatic, oval, with thread-like, eleven-jointed antennæ: hind-legs flat, oar-like; the neck has lateral odoriferous glands. The intestine has an appended cæcal sac, with many transverse folds. In swimming, the hind legs move simultaneously (Dyticus, &c.), or alternately (Pelobius). 24. Gyrinidæ—eyes divided by the edge of the head into an upper and lower series; antennæ short; hind-leg short, fin-like; they swim in circles, and fly as the last; larvæ centipede-like, with lateral abdominal appendages, and mouth as last. Some are marine as well as fresh water. 25. Hydrophilidæ—oval or semi-circular, with broad swimming hind-feet; antennæ six- (Sperchus) nine-jointed (Hydrophilus, Hydrobius); club-shaped; palps as long as antennæ. These beetles are recommended by Professor Klein as the best animals wherein to trace the structure of muscular fibres, and nerve endings therein. 26. Staphylinidæ (Brachelytra)—body long; elytræ short; hind-wing folded; antennæ 10–11-jointed; males sometimes heteromerous; larvæ like the perfect insect, with two hinder bristles to the abdomen, and a tubular anus; stomach, villous internally, preceded by a proventricle with chitinous ridges. 27. Paussidæ—antennæ 2–10-jointed, clavate; head trigonal; tarsus four-jointed; elytra long four-angled, with a fold at the outer angle; ventral rings four. 28. Hysteridæ—antennæ retractile, short, bent, the

three last joints dilated; tortoise-like beetles, which, when caught, feign death. 29. Silphidæ: Carrion beetles—antennæ clubbed; ligula bilobed; abdomen of six free moveable segments; anterior and middle legs with conical basal joints. Leptoderus from the Adelsberg cave is eyeless. 30. Scaphididæ—small, fungicolous; antennæ with a clubbed or capillary end; basal joint of fore-limb cylindrical; abdomen with a conical point. 31. Phalacridæ—small, oval, convex, with a small fourth tarsal joint; abdomen with five free rings. 32. Nitidularidæ—small, with antennæ clavate; legs short; male tarsi often heteromerous. 33. Colydidæ—antennæ clubbed, tarsus four-jointed; the last or last pair of the five ventral rings alone are moveable; the body has a sculptured surface. 34. Cucujidæ—body compressed, with moniliform (Cucujus), or clavate (Silvanus), or thread-like antennæ (Brontes); all the five ventral rings free. 35. Cryptophagidæ—antennæ with a 1–3-jointed terminal club; tarsi five- (Cryptophagus), rarely three- or four-jointed (Mycetophagus). 36. Dermestidæ—antennæ short, retractile; a single frontal eye. Anthrenus museorum is the pest of entomological cabinets. The larva of Dermestes lardarius is the bacon grub. 37. Byrrhidæ—oval; tibia folds into the femur like a penknife. 38. Parnidæ—antennæ clubbed, with retractile head; aquatic, but without swimming feet, and with a silky clothing, and a varnish-like coating. 39. Scarabæidæ (Lamellicornes)—antennæ short, the first joint large, the last three, or more, forming a lamellated club; eyes lateral. Dynastes has the clypeus united to the forehead, and the mandibles uncovered (sheathed in Cetoniæ, &c.) Melolontha, the cockchafer, is found on the leaves of sycamore, and other trees, to which it is very destructive. Ateuchus sacer was the sacred Scarabæus of the Egyptians. Geotrupes is the dung beetle. Lucanus and its allies have comb-shaped antennæ. 40. Buprestidæ—bright-coloured, long, flat beetles, with serrated antennæ; short legs; eyeless larvæ; cæca are appended to the stomach or proventricle, and often to the œsophagus (Anthaxia). 41. Eucnemidæ—cylindrical, with retractile antennæ, globular femora on the fore and middle pairs of legs; labrum indistinct. 42. Elateridæ—long, de-

pressed; labrum distinct; legs with linear tibiæ; prothorax with a chin process, directed forwards, and a basal spine fitting into a groove in the mesothorax; by this they can spring when laid on their back. Pyrophorus noctilucus is the firefly, emitting light from two spots on the thorax. The larva of Agrites segetum is the wire-worm dreaded by agriculturists. 43 Cebrionidæ — mandibles sickle-like; legs fossorial; prothoracic process bent upwards; larvæ like those of last. 44. Rhipiceridæ—antennæ between the eyes. 45. Cyphonidæ—mandibles short; ligula membranous, large. 46. Malacodermata—soft-skinned, leathery; females often wingless; mandibles short; tibiæ rarely with a terminal spine; this includes Lampyris, the glow-worm. The light-organ consists of a delicate-walled capsule, including polygonal cells, inclosed in a finely granular mass, and situated in the abdomen. The luminous rings are clear, waxy-like externally. Lamprocera, from S. America, has feeble light organs. Phosphænus has both sexes wingless. 47. Cleridæ—moderately large, with slender body, and membranous or horny ligula. 48. Xylophaga, wood-borers—cylindrical; head often covered by the neck-shield. Lymexylon navale is destructive to oak woods. Anobium pertinax, the "death-watch," makes its sound by striking with their jaws against woodwork; Ptilinus pectinicornis bores in books; Ptinus fur, the herbarium beetle, devours dried plants.

Order 14. Hymenoptera — wings four; naked, membranous, few-veined; fore pair larger; prothorax small, annular, as in Lepidoptera and Diptera, united with the mesothorax on the dorsal side, while its ventral part, which articulates with the head, remains free; females with an ovipositor; head free, with two large compound eyes, and usually three frontal ocelli; mandibles strong; maxillæ and labium united, and sometimes extended as a proboscis; both pair of maxillæ are freely articulated, allowing of their retraction; and the mentum is smaller than the palpigerous region of the labium; paraglossæ are also often largely developed; the antennæ often consist of a basal *scape*, and a terminal *funiculus* of 11–12-jointed linear joints, or may be of many

filiform segments; maxillary palps with six,—labial with four joints. The nervation of the wing is shown in the sketch. The eight or nine-jointed abdomen may be nearly sessile, but when of fewer segments it joins the metathorax by a narrow stalk (*petiole*). There is in the female post-abdominally often an aculeus inclosed in two valvulæ, or within a tube (terebra). The salivary glands are grape-like in bees, &c.; the stomach is long, annular, and complex; and in ants there is a gizzard. The short *vasa malpigii* may be many score. The female has no bursa copulatrix, but there is a receptaculum seminis, with an appendicular gland. Many have two post-abdominal glands, simple or branched, opening into a common vesicle, whose duct ends in a sting, by which they pierce the nerve cord of insects, on which their larvæ feed. The tracheæ often dilate into vesicles, especially about the base of the abdomen. The meso- and metathoracic ganglia are fused, as are often the last pair of the 5-6 ventral ganglia. The larvæ have 6-8 pair of *pedes spurii*, as well as the ordinary feet in some, while others are footless. The saccular stomach is at first aproctous, as the intestine does not communicate therewith until after the first moult.

Fig. 42.

Wing of Hymenopteron: 1, 2, humeral cells, 3, 4, 5, first, second, and third cubital cells; 6, radial cell; 7, 8, discoidal cells; *c* cubital veins; *p*, radial veins.

There are three sub-orders:—I. Aculeata—sting-bearers; larvæ aproctous, eyeless, footless, abdomen petiolate. This includes, 1. Apiaridæ: Bees—wings not folded; anterior with two or three (Bombus) cubital cells; sting barbed; maxillary sheath elongated, knife-like; labium suctorial. The basal joint of the hindermost tarsus is flattened, and often bristled, to collect pollen for the food of the larvæ. Many of the females are workers. They form hexagonal cells for their young, of wax, or (as Anthophora, &c.) of foreign bodies, glued together by saliva. Some bees lay their eggs in the nests of others (like cuckoos). Apis mellifica is the common honey-bee, whose female is the queen bee, and whose young are cared for by females with rudimental sex-organs

(workers). Osmia makes thimble-like cells. Xylocopa, carpenter-bees, cut passages in old wood. 2. Vespidæ, Wasps—often naked; antennæ slender, notched and bent; eyes reniform; prothorax elongated to the wing roots; maxillæ often leathery; wings longitudinally folded. They are solitary, or colonial, and the latter have workers, like those of bee colonies. The nests are of paper-like vegetable pulp. Vespa and Polistes are the ordinary social wasps, whose colonies consist often of workers, until the end of the season, when the males and females appear. In the latter genus parthenogenesis occurs. Polybia and Epipone chartaria build large conical nests in S. America. Eumenes, Odynerus, and other solitary genera build clay nests. 3. Crabronidæ—antennæ short, not bent; mandibular palp, six,—labial, four-jointed; forewings not folded, narrow; sting not barbed, nor broken on being used. The female either kills prey to feed her larvæ (Bembex), and brings it to them daily, or paralyses other larvæ by injuring their nerve-cord, and brings them in numbers into the nest, providing the young at once with enough food for their whole larval state (Cerceris, Sphex, &c.) Tachytes is a cuckoo wasp, like the nomade bees, laying eggs in the nests of Sphex. 4. Pompilidæ, Sand wasps—antennæ long; prothorax stretching to the wing roots; wings large, broad, the fore with three cubital cells; legs spiny. 5. Heterogynæ—sexes dimorphic; females wingless (Mutilla, &c.), or nearly so (Sapyga, Myzine, &c.); mostly parasitic on other Hymenopters. 6. Chrysididæ—metallic coloured, with bent 13-jointed antennæ; 3–4-ringed abdomen; one cubital cell on the forewing. 7. Formicidæ, Ants—colonial; males and females winged, but workers apterous, with small thorax, eyes, and no ocelli; an anal gland, secreting formic acid, which acts as an irritant. Some feed on the sweet, honey-like substance which they suck from Aphides. Formica rufa, the red ant, builds ant-hills; Polyergus holds individuals of other species as captives in its nest; Myrmecocystis has a globular abdomen; Atta cephalotes is the visiting ant of S. America.

Sub-order 2. Entomophaga—trochanter biannulate; ab-

domen petiolate. The females lay their eggs with an ovipositor or terebra, covered by two valves, in the bodies of the larvæ of other insects, in whose cavities the footless larvæ, when hatched, are endoparasitic. 8. Chalcididæ—antennæ bent, 4–6-jointed; terebra ventral; prothorax not elongated to the wing-root. Blastophaga is an agent in fertilizing figs. 9. Cynipidæ, Gall-flies—antennæ thread-like, 13–16-jointed; abdomen compressed. Cynips lays eggs in oak leaves and branches, forming nut-galls. Rhodites forms the "Bedeguar" on roses. Synergos (a cuckoo form) lays eggs on the galls of Cynips. 10. Proctotrypidæ—antennæ straight or elbowed, 10–15-jointed, rarely 8; minute black parasites. 11. Ichneumonidæ—thin, long, antennæ many-jointed, thread-like; terebra terminal, straight; abdomen attached to the upper side or to the end (Ichneumon) of the metathorax.

Fig. 43.

Apocrypta paradoxa. A fig parasite.

Sub-order 3. Phytophaga—abdomen sessile; ovipositor saw-like; larvæ with more than six feet, and proctuchous. 12. Tenthredinidæ, Saw-flies—antennæ thick at end; 3–30-jointed; metathorax with a deep notch above; eggs laid under the epidermis of leaves. Nematus lives in willow leaves. Tenthredo, the saw-fly, is common on roses, and the larva of one form, Athalia centifolia, is often destructive to turnips (Nigger caterpillars). 13. Uroceridæ, tailed or wood wasps—antennæ straight, thread-like, 11, 24-jointed; abdomen cylindrical, nine-ringed, with prominent terebra.

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* By mistake spelled Andoninia, 222.

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