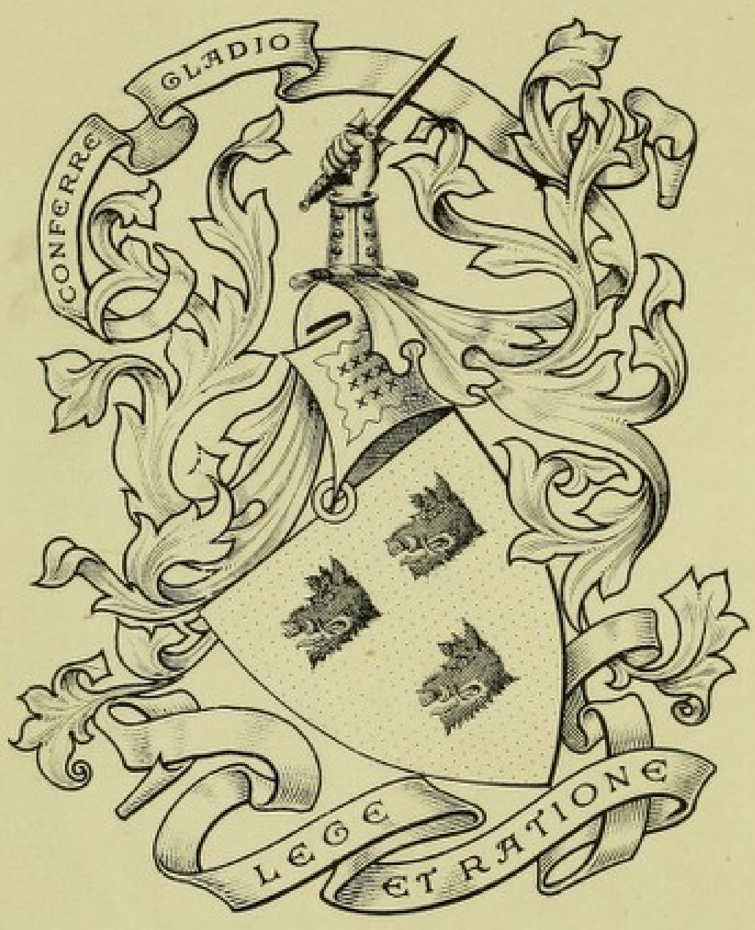

Edgar March Crookshank.

Saint Hill, Sussex.

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MANUAL

OF

COMPARATIVE ANATOMY

AND

PHYSIOLOGY

BY

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PREFACE

TO

THE THIRD EDITION.

The Third Edition of this work has been carefully revised by my friend Mr. G. Legge Pearse, who has made many important emendations, and to whom my thanks are very specially due. I have also gratefully to acknowledge much valuable aid from Mr. W. Saville Kent in revising that portion which refers to the Invertebrata, and also to thank Mr. J. Beswick Perrin for sundry corrections and suggestions throughout the work.

Manchester: *March* 1875.

PREFACE

TO

THE SECOND EDITION.

THE First Edition of this little book met with so ready an acceptance that I had reason for my hope that it would supply a want. The present edition is entirely re-written, and by considerable additions I have endeavoured to render it a more efficient text-book for students.

The Illustrations, drawn by Mr. Searson, curator of the Manchester School of Medicine, are taken from various standard works on Comparative Anatomy, including those of Owen, Cuvier, Lieberkühn, Rathke, Mivart, Huxley, Carpenter, Rymer Jones, Gegenbaur, Flower, Nicholson, Forbes, Allman, and Herbert Spencer. Some few are original.

I am indebted to Mr. Searson for much trouble which he has expended in framing the Index to this work, and also for continual assistance during its progress through the press.

PREFACE

TO

THE FIRST EDITION.

THE works on Comparative Anatomy and Physiology are so numerous, and many of them so splendid, that some apology seems necessary for the issue of such a sketch as the present little Manual. It is found in the very perfection of former treatises on the subject; a perfection which renders them so bulky and comprehensive, as almost to preclude students, who have a multiplicity of other subjects to prepare, from gaining the particular facts they require, for they naturally dread *tentare horridas vias* of such large tomes as those of Rymer Jones or Owen. This difficulty is particularly felt by gentlemen who are preparing for their second B.A. at the London University. It is a perfectly well-known fact to those who come much in contact with men going up for this examination, that their 'bête noir' is the *Animal Physiology* which forms one of the subjects, and it is with the definite hope of, in some slight measure, smoothing away this difficulty that the following little treatise has been prepared. The principal merit which it possesses, that of brevity, would have been rendered impossible if the ordinary processes of physiology, which form the subject matter of works on human physiology, had been described; nor is the omission of such matter to be lamented, as manuals of the greatest excellence upon this subject are within the reach of every student.

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MANUAL

OF

COMPARATIVE ANATOMY AND PHYSIOLOGY.

CHAPTER I.

NATURE AND COMPOSITION OF ANIMAL CELLS—DIFFERENCE BETWEEN PLANTS AND ANIMALS—SUB-KINGDOMS, CLASSES, ORDERS, FAMILIES, GENERA, AND SPECIES—DIVISIONS OF THE ANIMAL KINGDOM.

THE ultimate composition of every animal is either granular or cellular; all, indeed, but the very simplest organisms being developed from cells, and a similar structureless, intercellular matrix, or *blastema*.

The definition of an animal cell has become more and more simplified, until it is now merely described as a *nucleated mass of protoplasm*—the protoplasm being a transparent substance, partly albuminous and partly amyloid, which forms the physical basis of every living creature.

Although it is not essential that an animal cell should possess a cell wall, yet an envelope called the *periplast*, which contains the semifluid *endoplast*, *protoplasm*, or *bioplasm*, is generally present, within which, in all except the very lowest forms, a small body termed the *nucleus* is found, which in its turn contains a still minuter body, the *nucleolus*.

As indicated in the first paragraph, however, we cannot predicate with strict correctness the cellular character of all animals, for some of the lowest organisms may, and do, consist of unnucleated protoplasm, *e.g.*, many of the Rhizopoda simply consist of semifluid sarcode, which cannot be said to be enclosed in a cell wall, inasmuch as the processes which are constantly being thrown out on all sides coalesce with one another much as several minute globules of oil may run together to form a single globule.[1] This nonnucleated protoplasm, however, is

[1] It may here be added that the microscope discovers no difference between the embryological protoplasm of an amœba, a mollusc,

possessed of some of the most remarkable attributes of animal life ; thus it is capable by some unknown, and perhaps unknowable force, of producing architectural structures (*e.g.*, the shells of Foraminifera and Rhizopoda), of the greatest regularity and most singular beauty, of actively searching for prey, and of moving from place to place.

The Foraminifera are now believed to be nucleated.

It is only by a process of aggregation that the ultimate particles of the protoplasm, which we must conceive to be granular, build themselves up into a cell, so that we should regard a cell as representing the second degree of complexity in animal life.

It is easy to understand how cells once formed may remain separate, or may grow together so as to form fibres, or tubes, or membranes, which form the fluid and solid constituents of animals, though some structures, *e.g.*, homogeneous membranes, may be developed directly from the fluid protoplasm without the intervention of cell formation.

New cells are formed in various ways, each of which typifies a different mode of reproduction of the species.

By one mode, a cell and its contained nucleus splits into two distinct cells, each containing its proper nucleus. This is the *fissiparous* mode of development. By another method, a cell develops a small bud from one part of its envelope, which, after growing, becomes detached from the parent cell, and assumes the form and function of a perfect cell. This is *gemmiparous* development. A third plan is for the nucleus to divide into one, two, or more nuclei, which either burst their way out of the cell wall, and then become developed into perfect cells, *exogenous* development ; or, after their division, grow up within the envelope of the parent cell into mature cells, *endogenous* development. Their multiplication thus provided for, animal cells undergo various changes in form and composition. Some lengthen out into thin thread-like bodies, which, becoming connected end to end with other similar cells, constitute the histological elements of the fibrous tissues; others remain as circular cells with or without *periplast*, and constitute the cells of the

fish, or of man, yet each inevitably tends to produce its like ; this is due to the atoms of each embryo possessing the potential morphological and physiological properties of the parent organism, hereditariness impressing itself even to the transmission of moral qualities. Thus the impregnated germ-cell, has within it all the physiological possibilities of the future being : it carries with its law of growth and its doom of decay ; there is already laid down in undistinguishable, but still certain and unalterable, characters, the nature of the future being, the physical form, the shape of the frame, and the colour of the eye, nay, even the moral and intellectual being is already there in embryo, the mental powers which shall develop into a ruler of men or a serf, the moral qualities of a hero of a scamp.

blood, the chyle, &c. ; others become loaded with earthy or calcareous particles, and so build up the skeletons of animals ; others become converted into skin, by being flattened out and dried ; others, again, remain distinctly cellular, and constitute the animal secretions.

There is very little difference between the individual *vegetable* and *animal* cell ; but the points to be chiefly noted are these : the *vegetable* cells are always *perfect* cells ; they are surrounded by very little blastema, they are mutually independent of each other, and they require for their nourishment a pabulum drawn from the inorganic world. On the other hand, *animal* cells are frequently *imperfect*, being deficient in a cell wall ; they are always surrounded by a considerable amount of blastema, they are more or less mutually dependent on each other, and they derive their nourishment from the organic world alone. By this latter property the two kingdoms supplement each other's requirements, and so maintain the natural cycle of life. The animal dies, and is resolved into the inorganic world, in which condition it becomes food for the plant ; the plant then reconverts this pabulum into organic matter, when it re-becomes meet food for the animal.

The dawn of animal life is, as may be gathered from what has gone before, indistinct, and often difficult to discern. The border-land between the vegetable and animal kingdom is the scene of a perpetual conflict of opinion, doubtful forms changing sides more than once during the contest. Perhaps the most important differential characteristics of animals are, first, the fact of their food being always derived from the organic world, and, secondly, the fact that in their physiological processes they are *synthetical*, whilst vegetables are *analytical ;* in other words animals take in oxygen and give out carbonic acid, which is formed in their system ; whilst plants (with the exception of some fungi which require complex organisms for nourishment) take in carbonic acid, and, breaking it up into its component parts, give out the oxygen and retain the carbon. It may be further said that all animals, including the lowest Protozoa, take in their food in a solid, though it may be in an infinitely minute or granular form, while plants absorb their pabulum in a fluid state. This distinction is indeed of high importance, as affording the only recognisable difference between the two kingdoms in accordance with our present knowledge.

It follows from these facts that, with the exception of the last named, there is no single circumstance which separates the two kingdoms. The lowest plants and the lowest animals approach each other more closely than the highest plants and the lowest animals, *e.g.*, the position of bactriæ and vibriones is still doubtful, but no one could doubt the vegetable nature of any exogen, or the animal nature of any vertebrate. The lowest plants and animals seem indeed to meet upon a common platform, whence it seems uncertain to which kingdom they will tend. Life, therefore, does not form a continuous ladder; the two kingdoms diverge at the very beginning, and do not serially succeed each other. This is equally true again of the animal kingdom as of the vegetable, for we find that the sub-kingdoms into which it is divided do not serially succeed each other, but one after another diverge at some rung of the ladder leading in quite a different direction to that of the parent stock.

The whole animal kingdom is divided into sub-kingdoms, classes, orders, families, genera, species, and varieties, with constantly less important and diminishing lines of demarcation between the divisions as we descend the list. Placing them tabularly :—

Sub-kingdoms represent the primary divisions of animal kingdoms, each representing an essentially different type of structure.

Classes are the largest divisions of the sub-kingdom, and the most natural of all. They resemble each other in their fundamental plan, but differ in the way that the plan is carried into detail.

Orders are smaller divisions, having all the essential characters of the classes, but differing in further detail.

Families are still smaller divisions.

Genera are subdivisions of an order.

Species are groups of individuals always fertile, and invariably reproducing their like—

To take an illustration—a spaniel is a 'variety' of the 'species' dog, which is placed in the 'genus' Canis (containing also the jackal and the wolf), in the family of Digitigrada, in the order 'Carnivora,' in the class of Mammalia, and in the sub-kingdom of the Vertebrata.

The sub-kingdoms at present recognised are—

Vertebrata.

Mollusca. Annulosa.

Molluscoida. Annuloida.

Cœlenterata.

Protozoa.

Protozoa is the lowest sub-kingdom, Vertebrata is the highest. It is to be observed, however, that we do not reach Vertebrata by a single line, but that the sub-kingdom Cœlenterata branches into two streams, each of which conducts us to the top of the animal ladder.

CHAPTER II.

THEORY OF EVOLUTION—SKETCH OF EVOLUTION OF THE ANIMAL KINGDOM—PHYLUM OF THE SUB-KINGDOMS.

THE infinite variety of animal forms which exist, and have existed, are believed by most naturalists of the present day to have appeared upon the earth by a process of evolution from some preceding form. This theory is carried back to the very origin of living beings, and holds that the simplest organisms are evolved from a new arrangement of material molecules which were previously unendowed with vitality. This doctrine assumes that the Divine Governor and Architect of the Universe has established certain laws by which the gradual and progressive evolution of life from dead matter, and of higher from lower forms, is guided and ruled.

Several factors are probably at work in determining this genesis of new species. Of these the most powerful is Natural Selection, or, as it is styled, the law of the survival of the fittest. This law shows that any animal possessing any sort of advantage over its congeners is likely to transmit the peculiarity to its offspring, and finally, in the continual struggle for existence, to supplant the less favoured forms. An immense variety of developmental or evolutional changes may be explained by this law, but alone it is not sufficient to explain all, and we consequently find that use and disuse of parts, sexual selection, the influence of surroundings of every kind, and other causes, contribute to give rise to the evolution of new species. It is by no means necessary to assume that some one simple organism underlies, and has given origin to, all succeeding animal forms, as some indeed are inclined to believe ; on the other hand, it is more probable that the same incident forces, constantly operating, would frequently meet with many different materials, and so would give rise to various results in many places, and perhaps at many times. Anyone who has watched the crystallisation of some saline solution beneath the electric light, may rationally figure to himself the simultaneous but multitudinous burst of life which probably is for ever occurring among the simplest organisms.

It is perhaps possible to give a sketch of the evolution of animal forms in a few sentences sufficient to illustrate the general doctrine.

After the evolution of such simple animals as the Rhizopoda, the lowest of which we have seen to be mere masses of unnucleated protoplasm, the first step would be for the sarcode to acquire a denser envelope. This change would be followed by the development of cilia from its surface to supplant, as locomotive organs, the pseudopodia which would no longer be protrudible; one part of the envelope would then become indented, to permit of the readier ingress of food, and so the Rhizopod would evolve the ciliated Infusorium. Through the Infusoria we reach such simple Cœlenterata as the Hydræ, which give us a clue to further progress; the sponges, an offshoot from the Flagellatæ, indicating the most direct line of evolution. The animals now reached are cellular in structure, and constantly develop congeries of cells, or buds, from the sides of their body, which may either remain attached to the parent organism, or may become detached, when they will themselves grow up into forms like those from which they sprung. If these buds remain attached to the parent they may nevertheless become matured, and in this manner we are able to understand the development of such compound animals as Salpidæ or Spongidæ, or the compound Actinozoa. Thus, *e.g.*, such animals as Sponges are formed by an integration (by simple adhesion as it were) of a vast number of minute but independent organisms, which are loosely united, to form the entire colony, each organism subserving some function of the compound animal. These changes are simply due to a process of gemmation, which perhaps may be made clear by the accompanying diagram, for it is easy to understand how such a creature as *a* might, by budding, evolve an organism like *b*.

Fig. 1.

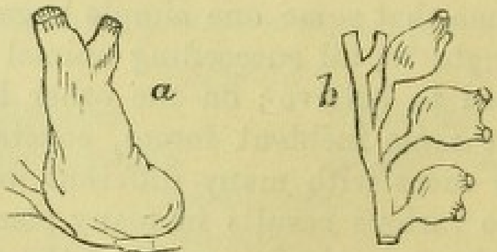


DIAGRAM TO ILLUSTRATE THE EVOLUTION OF ASCIDIOIDA.

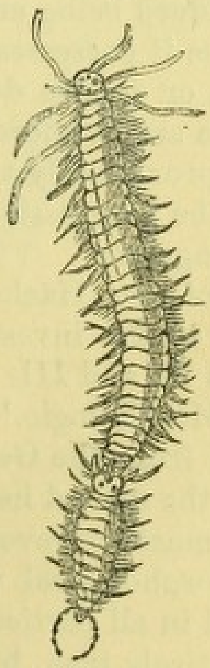
a Phallusia mentula.

b Perophora—designed to show how a compound Ascidian, growing from a common stolon, may be evolved from a solitary and simple form.

Now, when each of these gemmiparously produced individuals, still attached to the parent form and to each other, enjoy equal advantages on every side, the result will be morphological uniformity in the individual organisms, but when the individual zoophytes do not possess equal advantages a certain differentiation will take place. If, for example, the buds, instead of appearing laterally, are produced linearly one behind another, it is manifest that the two end ones will enjoy much greater freedom of movement than the central ones. Now it is exactly this step which has taken place in the Annelides, and as a consequence the terminal segments, for the various segments are here held to be nothing but imperfectly separated individuals, become the head and tail of the animal.

It is now presumed that the integration has been carried to the extent of merging the separate individuals entirely in the single life of the whole organism. The force of this argument, viz. that animals of the annelid and annulose type are composed of segments which are really imperfectly separated individuals, gains much force from the circumstance that linear gemmation does occasionally become complete, each separate segment becoming a perfect annelid. The accompanying diagram illustrates this linear gemmation taking place in the Syllis, one of the Annelida.

Fig. 2.



Cirrhatula, one of the Annelida, showing the development of two distinct individuals by spontaneous segmentation from a single animal.

The Annulose animal is a decided advance upon the Annelid, but the same principle of evolution may still be traced. Embryology affords the best guide to the naturalist in tracing genealogies, and morphological comparisons of lower with higher members of this class, showing that they are composed, like Annelides, of the aggregates of imperfectly separated individuals, zones, or segments, arranged along a longitudinal axis, now called 'somites,' which as we ascend the class become more and more differentiated in form and function, until in such creatures as the Crab or the Spider there is little trace left of that 'vegetative repetition' which is so manifest in the common Earthworm.

Having, however, reached the class of Insects we can ascend no higher in the animal scale in this direction; so to trace the evolution of

Mollusca and Vertebrata we must try back again. Reverting once more to the Cœlenterates we find them merging by fine, and, indeed, almost imperceptible, degrees into animals sometimes free and sometimes compound, called Molluscoida. One class of the Molluscoida, termed Brachiopoda, are enclosed in bivalve shells, and from one part of their body being more advantageously situated than the opposite, they become asymmetrical. These Brachiopods conduct us to the large sub-kingdom of the Mollusca, which cease to exhibit any trace of vegetative repetition.[1]

They are never compound, and never multiply gemmiparously or fissiparously, but always by the congress of the sperm cell and the germ cell. The highest Mollusc, like the highest Annulose animal, leads us no higher; but another class of the Molluscoida, the Ascidioida, in the possession of a dorsal cartilaginous rod (resembling the notochord of Vertebrates), in the mode of their development, and in the position of their nervous system, conduct us to the lowest vertebrate—a fish, called the Lancelet, or Amphioxus. This animal may very easily be supposed to be the prototype of all the other vertebrate classes, although its own organisation is of the simplest character, possessing neither brain, nor heart, nor true vertebrate column, and indeed being entitled to rank among the Vertebrates, solely because it possesses the dorsal rod before mentioned, the notochord, or chorda dorsalis, from which the vertebræ in all Vertebrata are primordially developed. Supposing this sketch to be approximately true, the accompanying table (I.) will illustrate the progressive evolution and divarication of the several sub-kingdoms.

Professor Häckel has devoted much time, learning, and talent to the investigation of these lines of descent, and the Tables II. and III. are adopted from his great work on 'Generelle Morphologie.' The first gives an outline, much abbreviated from the German professor's work, of the whole animal tree; the second indicates the phylum of the vertebrate classes.

It must, however, be conceded that whilst evolution explains the morphological varieties of animals, evolution itself is not proved in all particulars. This does not imply that evolution is not entirely true, but simply that at present we are not justified in regarding it as demonstrated. The chief difficulty it has to

[1] According, however, to Professor Morse the Embryological development of the Brachiopods would indicate their close relationship to the Annelides. The same authority associates the Polyzoa also with the Annelida, and considers that the lower Mollusca (Lamellibranchiata) have been evolved from the Tunicata.

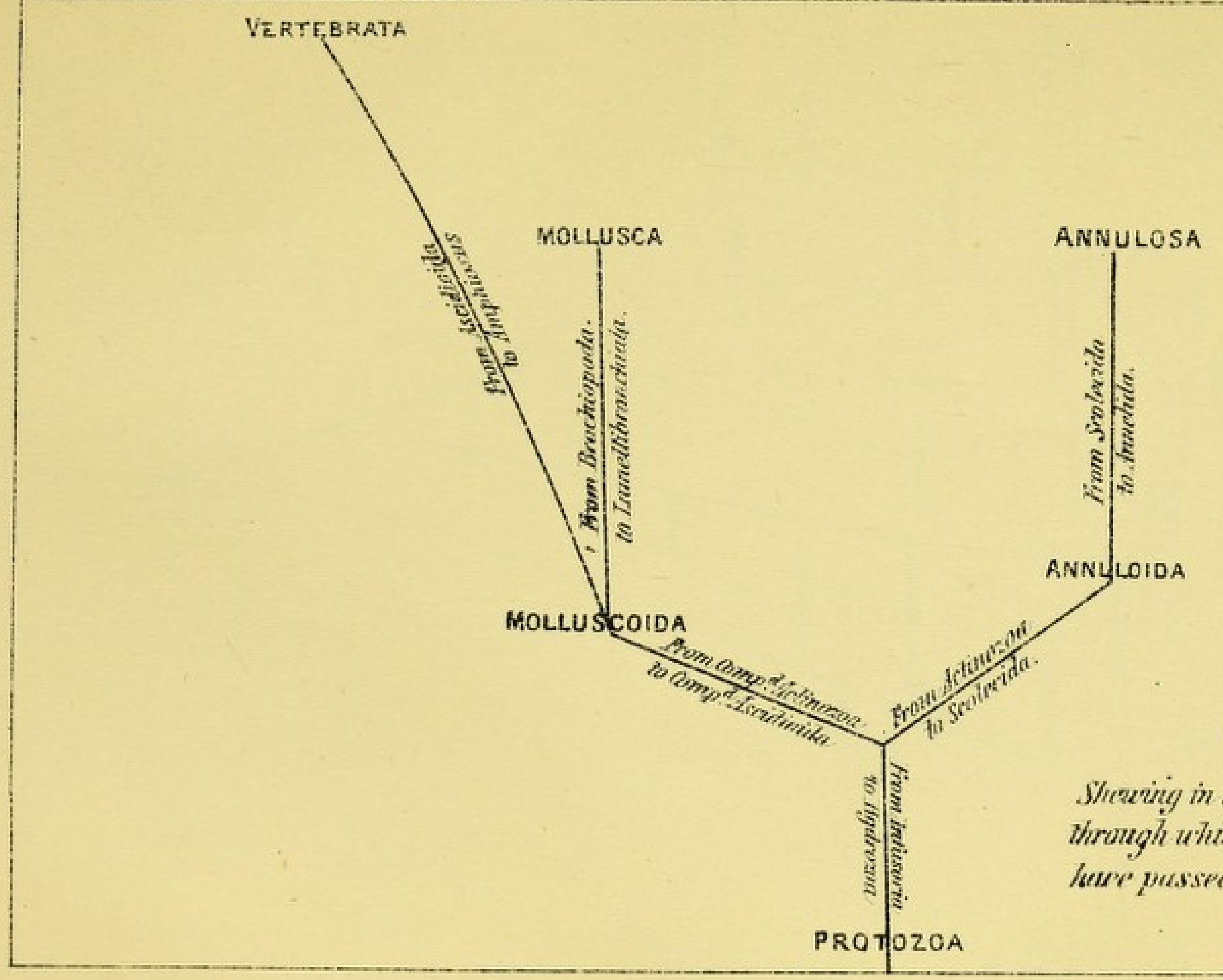
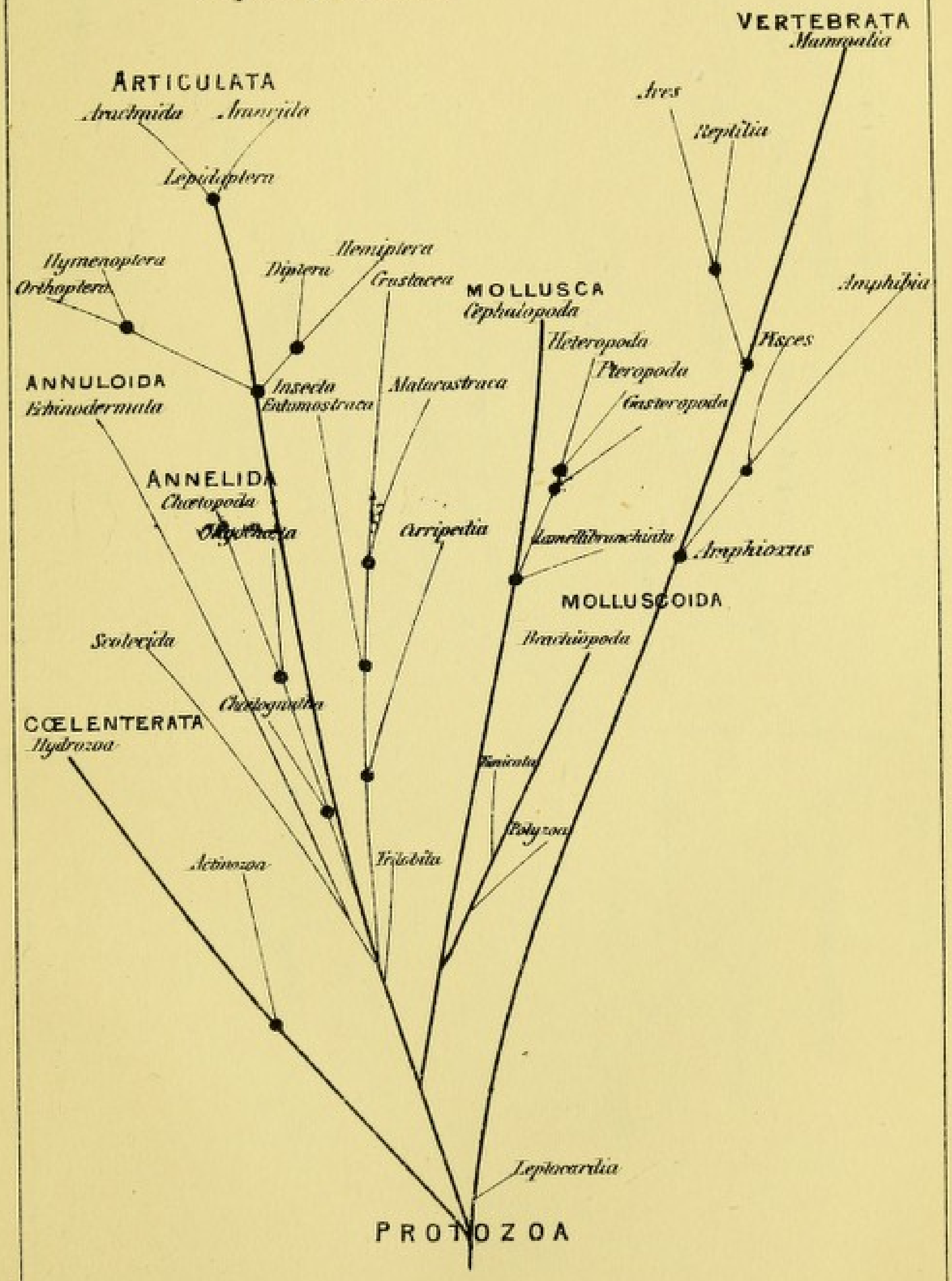


TABLE I.

Shewing in outline the probable channels through which the various sub-kingdoms have passed during their evolution.

TABLE II

Phylum of the Animal Kingdom, showing the probable genealogical arrangement of the principal classes



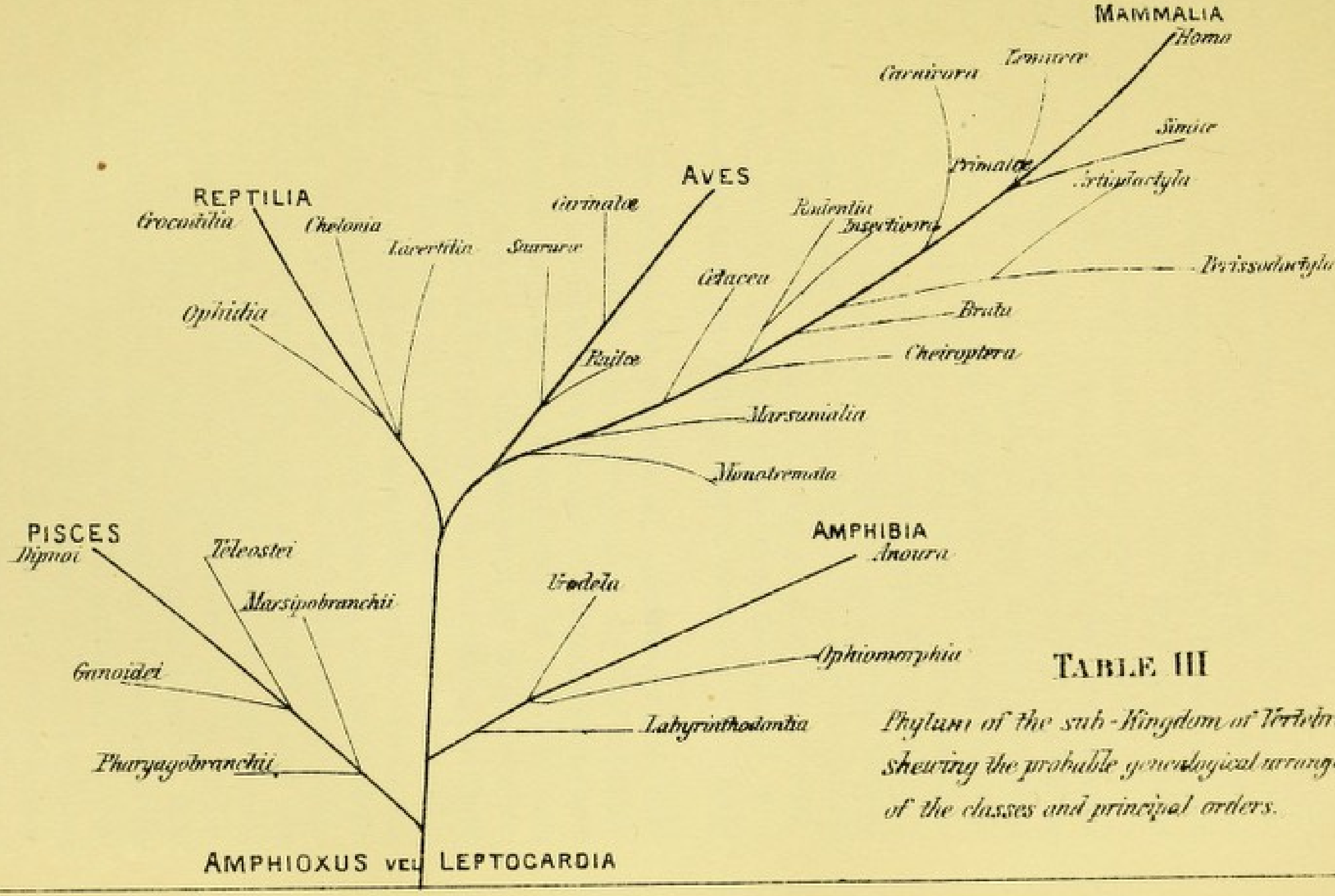


TABLE III

Phylum of the sub-Kingdom of Vertebrata shewing the probable genealogical arrangement of the classes and principal orders.

contend with is accounting for its incipient stages of useful structures—an example will serve to define what is meant. Mr. Mivart, who in his 'Genesis of Species' has called special attention to this point, says, 'Let us consider the mammary gland, or breast. Is it conceivable that the young of any animal was ever saved from destruction by accidentally sucking a drop of scarcely nutritious fluid from an accidentally hypertrophied cutaneous gland of its mother? And even if one was so, what chance was there of the perpetuation of such a variation?' To this Mr. Darwin replies: 'It is admitted by most evolutionists that mammals are descended from a marsupial form; and if so the mammary glands will have been at first developed within the marsupial sack. In the case of the fish Hippocampus, the eggs are hatched, and the young are reared for a time, within a sack of this nature; and an American naturalist, Mr. Lockwood, believes from what he has seen of the development of the young, that they are nourished by a secretion from the cutaneous glands of the sack. Now, with the early progenitors of mammals, almost before they deserved to be thus designated, is it not at least possible that the young might have been similarly nourished?'

This reply can scarcely be considered satisfactory; to base an argument involving such vast consequences as the explanation of the origin of the distinctive feature of the most important class in the animal kingdom upon the *belief* of any one man having seen the young of the fish nourished by milk-secreting organs, and from that belief to found such a conclusion without any trace of such organs in the intermediate classes of reptiles and birds, is not an example of the scientific use of the imagination. This argument of Darwin's is moreover rendered abortive by the fact that it is the *Male* and not the *Female* Hippocampus within whose pouch the ova are deposited and the embryos are developed: and it is further discredited by recent research showing Mr. Lockwood's supposition to be incorrect. Be that as it may, however, it is quite possible that the truth of evolution *will* be demonstrated to the satisfaction of all; but the minds of men need not to be perturbed on that account—the marvels of the Reign of Law are as full of lessons to us as the doctrine of a special creation for every living being; indeed, the idea that the Almighty was content once and for all to found His laws of life, and then to allow them to work in all the marvellous directions they have assumed, is a grander and more ennobling belief than the dogma of special creations. Let it not be supposed that the mystery is removed from any living being by knowing that it conforms to laws which have been from the beginning, and that it perchance even owes its existence to similar laws. True science indeed is a teacher of true religion, for it shows us that we cannot, and by the nature of our minds we never can, get beyond a realisation of the *effects* of the law ; we shall in our present state be ever unable to understand the primary cause—and must be content to conclude our investigation by saying 'God so willed it.' Examine the movements of an Infusorium or of a Spermatozoon, and whatever your theory of their origin may be, ask yourselves how much evolution and science have hitherto done towards explaining the nature of that wondrous life you see. We see the structureless protoplasmic mass of a Rhizopod digest nutriment as perfectly as we ourselves can ; and after a time, the *life* being gone, we note that these processes are arrested ; do any number of such terms as osmosis, dialysis, catalysis, and so forth, advance our knowledge of the process by which this is effected ? Science has won sufficient victories from ignorance and superstition to justify confidence in her truth, but sufficient remains behind the veil to discourage arrogance.

In reference to this subject, too, it must be remembered that in examining any member of the animal kingdom it is not sufficient merely to regard its bodily structure. Every animal indeed requires regarding in a threefold manner, morphologically, physiologically, and psychologically, for it is only by such a process that we can clearly assign any animal its true place in Nature, *e.g.*, morphologically, Man must be included in the same order as the Simiadæ ; physiologically, he must be ranked in the family of the Catarrhinæ ; while psychologically he merits a sub-kingdom to himself.

CHAPTER III.

EVIDENCE AFFORDED BY GEOLOGY—TABULAR VIEW OF THE GEOLOGICAL STRATA WITH IMBEDDED FOSSILS—MODES OF REPRODUCTION AMONG ANIMALS—HOMOLOGIES AND ANALOGIES—CORRELATIONS.

So far as it goes, the testimony of the rocks is corroborative of the doctrine of evolution, and as the science of geology progresses it becomes ever more and more so. There are, nevertheless, many and serious breaks in the chain ; the evidence, in other words, is imperfect. This is chiefly due to two causes, firstly, the fact that but a very little portion of the earth's crust has yet been examined (every fresh field, indeed, discloses fresh connecting links), and, secondly, from the fact that many organisms are in their very nature so perishable that a lasting record of them is not to be looked for.

The following is a tabular view of the principal strata, given in the order of their natural superposition, and with a few examples of the fossils found imbedded in them :—

Periods	*Strata*	*Examples of Animal Remains*
	POST TERTIARY	Living Animals and Man.
KAINOZOIC OR TERTIARY	PLIOCENE . .	Fish, Amphibia, Reptilia, Aves, Mammals, many extinct forms.
	MIOCENE . .	Most mammalian orders represented. (Dinotherium, Mastodon, Marsupialia.) Birds, Reptiles, Fish, Mollusca, Annulosa, Protozoa.
	EOCENE . .	Mammalia (Cheiroptera, Insectivora, Carnivora, Artiodactyla, Perissodactyla, Anchitherium), Mollusca (Oliva), Insecta (Butterflies), Foraminifera (Nummulites), Birds, Reptiles, Fish.
MESOZOIC OR SECONDARY	CRETACEOUS .	Belemnites, Ammonites, Gasteropods, Reptiles (Iguanodon), Crinoids, Mammals (Palæotherium), Pisces, (Squalacei), Saururæ.
	LIASSIC or JURASSIC	Birds (Archeopteryx), Encrinites, Echinodermata, Reptilia, (Ichthyosaurus, Plesiosaurus, Megalosaurus, Dinosaurus).
	TRIASSIC . .	Birds, Encrinites, Earliest Mammal (Monotremus), Gasteropoda, Reptilia, Labyrynthodon.
	PERMIAN (New Red Sandstone) .	Reptiles and Fish (Squatina).
	CARBONIFEROUS . .	Earliest Saurians (Archigosaurus), Pisces (Selachii).

Periods	*Strata*	*Examples of Animal Remains*
PALÆOZOIC OR PRIMARY	DEVONIAN (Old Red Sandstone) .	Fish (Ganoids), Corals, Cephalopods (Ammonites), Trilobites.
	SILURIAN . .	Placoid Fish, Brachiopods, Trilobites, Corals.
	CAMBRIAN . .	Protozoa, Brachiopoda, Crustacea (*e.g.* Trilobites).
	LAURENTIAN .	The Eozoon Canadense, a giant Foraminifer, the only fossil and the oldest fossil.

Reproduction.—One of the most essential characteristics of animals is that they reproduce their like—the processes, however, by which this is accomplished are various. Most frequently animals give rise to offspring by the union of the contents of the germ-cell and the sperm-cell, and such a mode of reproduction is called *sexual* reproduction ; but other animals produce without this sexual congress, such method being termed *asexual* or *agamogenetic* reproduction. The latter may take place in several ways. Subjoined is a table enumerating the principal modes in which reproduction is effected :—

I. Sexual. The result of the union of the sperm-cell and the germ-cell.

II. Non Sexual or Agamogenetic.

1. By gemmation or budding—*e.g.*, the Hydræ and Spongidæ.

2. By fission—*e.g.*, some Annelides.

3. *Internal Gemmation.*—By the formation of gemmæ or buds within the investing sac—*e.g.*, Gregarinida and Cestoidea.

4. *Alternation of Generations.*—The process by which an ovum produces a creature quite different from its parent, but from which an animal is developed resembling the parent ; this is effected in the first instance by a process of gemmation, or by the division of the first product of the egg, *e.g.*, Hydrozoa and some Tunicata.

5. *Parthenogenesis.*—The process by which unimpregnated eggs give rise to living animals which go on producing similar animals, until finally they become sexual and produce offspring sexually, *e.g.*, certain forms of Moths and Silkworms. The peculiar process in Aphides is an instance of alternation of generations.

Homologies.—This term will occur so frequently in the following treatise that it is necessary to define its meaning. Parts are said to be homologous when they are morphologically alike, *e.g.*, the arm is homologous to the leg and the separate bones of the one to the separate bones of the other ; one vertebra is homologous to another ; the fin of a fish, the paddle of a whale, the wing of a bird, the leg of a quadruped, the arm of a man are all homologous. When homologous structures succeed each other in a right line, as, *e.g.*, the segments of a worm or the bones of the spine, 'serial homology' is the term employed ; when similar structures are placed on either side, the parts are said to be laterally homologous.

When, however, structures resemble each other functionally, but not morphologically, they are said to be analogous structures ; *e.g.*, the wing of an insect and the wing of a bird are analogous, not homologous structures.

Correlations.—Among the most curious and obscure laws which govern animal forms is the law of correlation. We are without any clue to solving this strange law, but numerous instances have been collected of its existence. A few illustrations will suffice to show the character of the law ; tom cats with blue eyes are always deaf ; in the Swiss valleys, enlargement of the thyroid gland in the neck is correlated to peculiarities in the conformation of the skull and brain ; 'pigeons with feathered feet have skin between their outer toes ; pigeons with short beaks have small feet, and those with long beaks large feet.' 'Hairless dogs have imperfect teeth ; long-haired and coarse-haired animals are apt to have long or many horns.' The possession of a vertebral column correlated to the possession of a respiratory heart and of a portal venous system. While most correlations are obscure in their meaning, the meaning of others is traceable enough ; as *e.g.* the correlation of flat molar teeth to a long and complex intestine, or of long canine and pointed teeth to a short and simple alimentary canal, or extreme perfection of eye-sight to powerful organs of locomotion, or of flat vertebræ and a fish-like form of body. Many pathological correlations exist, some of which are apparently understood ; such, *e.g.*, are the correlation of psoriasis and gout ; incurved finger-nails and tuberculosis ; interstitial keratitis and constitutional syphilis, and so forth. Others, again, of a purely physiological kind, assist us in classification, though their meaning is unknown ; such correlations, *e.g.*, as the cloven foot and deciduous frontal horns are of this character.

CHAPTER IV.

SUB-KINGDOM: PROTOZOA—CLASSES: GREGARINIDA, RHIZOPODA, SPONGIDA.

Definition.—Minute animals, generally aquatic, composed of a soft sarcode, which is in some instances ciliated. The sarcode contains vesicles which constantly change their shape, owing to a power of contraction residing in the protoplasm, and similar to muscular action. These vesicles are called 'contractile vesicles.' Protozoa possess neither nervous system, circulatory organs, or alimentary canal. They are, as a rule, fissiparous or gemmiparous in their reproduction; but a few multiply by the sexual congress of sperm and germ cell. Some of these structureless masses of protoplasm secrete around them a calcareous shell of great complexity and beauty, in which they dwell. As a rule, they are capable of locomotion, and when this is the case it is effected either by '*pseudopodia*,' which are protrusions of the body sarcode; by *flagellæ*, which are whip-like bristles; by cilia, which are only present in the higher forms; or by contractions of the body-walls themselves.

PROTOZOA are primarily divided into animals which do not possess any oral orifice, the *Astomata*, and into those possessing a mouth, the *Stomata*.

They contain the following Classes and Orders:

ASTOMATA.

Class I. Gregarinida.

Class II. Rhizopoda.

Orders. Monera.
Lobosa or Amœba.
Reticularia or Foraminifera.
Radiolaria.

Class III. Spongida.

Orders. Keratosa.
Silicea.
Calcarea.

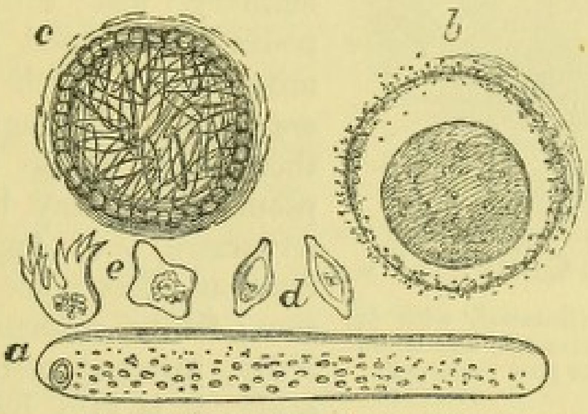
STOMATA.

Class IV. Infusoria.

Orders. Cilata.
Suctoria.
Flagellata.

Class I. GREGARINIDA (gregarius; grex, *a flock*) comprise the simplest of all animal forms. They are parasitic, and as a rule microscopic, varying in size from a pin's head to half an inch in length. They infest the intestines of insects, the cockroach more frequently than others, and are sometimes provided with hooklets, by means of which they gain firm hold. They are circular or elongated in shape, provided with a cell-wall, granular contents, a nucleus and nucleolus. They multiply by internal gemmation—becoming first of all encysted, then the nucleus disappears, and the protoplasm breaks up into a number of little bodies called navicellæ, which, finding their proper habitat, develop into adult Gregarinida. The Gregarinida move by the alternate elongation and contraction of

Fig. 3.



GREGARINÆ OF THE EARTHWORM.

a, Adult Gregarina; *b*, the same encysted; *c*, contents divided into pseudonavicellæ; *d*, free pseudonavicellæ; *e*, free amœbiform contents of the pseudonavicellæ.

the body-wall, which is due to the contractile power of the contained protoplasm.

The simplest of these amorphous forms, the *Protogenes*, is unicellular, and thus affords us an example of a living creature consisting of nothing but a single animal cell; this cell, however, is capable of absorbing nutriment and converting it into its own substance.

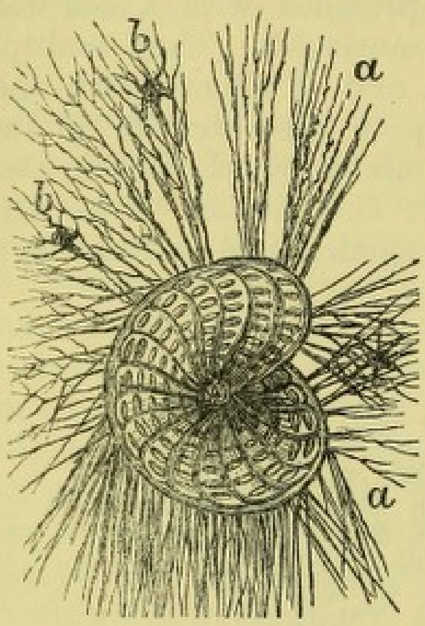
Psorospermiæ are parasitic Protozoa, infesting the intestines of fishes, and form another group of Gregarinida.

Class II. RHIZOPODA (ῥίζα, a root; πούς a foot). The integumental sarcode in these minute organisms is prolonged into processes which are sometimes broad and stunted, at others long and thread-like. The soft mass is most frequently enclosed in delicate lime shells, perforated by numerous foramina, through which the long processes or pseudopodia project.

Order 1. **Monera** (μόνας, unity). Minute marine Rhizopoda lying at the bottom of the sea. Reproduction takes place by fission. They are circular in shape when at rest, and only differ from the Foraminifera in the absence of a 'test' or shell.

Order 2. **Lobosa,** often called Amœba from the Protean changes of shape which these tiny creatures undergo, are fresh-water Protozoa which perpetually protrude blunt and broad pseudopodia which do not anastomose. They are composed of two layers, an outer layer, the 'ectosarc,' which furnishes the pseudopodia, and an inner coat, the 'endosarc,' which contains the contractile vesicles. Sometimes the animals of this order secrete a leathery 'test' with the pseudopodia all disposed at one extremity, upon which the creature crawls, *e.g.* 'Difflugia'; in others there may be no test, and the pseudopodia may be protrudible anywhere, *e.g.* Amœba. Reproduction takes place by, 1stly, fission; 2ndly, external gemmation; 3rdly, internal gemmation; and 4thly, it is said, by the congress of sperm and germ cells, the ova being contained in the nucleus, and the spermatic elements in the nucleolus.

Fig. 4.



A Foraminifer (Rotalia), with (*a*) pseudopodia extended, and entangling (*b*) minute prey (*enlarged*).

Order 3. **Reticularia,** vel **Foraminifera,** are marine Protozoa living principally at the surface of the sea, their dead shells sinking and accumulating in the bed of the ocean, sometimes three miles from the surface. It is a very numerous order, so numerous, indeed, that though the individuals are generally microscopic, their aggregates form vast tracts of sand and chalk in many parts of the world. A Foraminifer is a little mass of nonnucleated protoplasm, surrounded by a lime shell secreted by the protoplasm, which also forms a slight external coating, and furnished with long and interlacing pseudopodia. They are divided into *Perforata* and *Imperforata*, according as the shell is or is not perforated for the passage of the pseudopodia: or, according to another system, whether the shell is perforated by a simple (Lugæna) or many apertures (Globigerina) for the passage of the pseudopodia: the terms *Monothalamous* and *Polythalamous* best indicating this distinctive feature.

The shells differ widely in their construction and consistence, being either *porcellaneous*, when they are never penetrated;

vitreous, when they are always perforated ; or *arenaceous*, when they may or may not be perforated. They are, however, never *siliceous*, as they always are in Polycystina.

Again, they differ in the construction of the shell ; thus some, called *Monothalamia*, consist of a little sarcode, which is contained in a single lime cell, *e.g.* Lagena, or Entosolenia ; others again, called *Polythalamia*, construct many chambers in their shell, the septa or divisions of which are perforated by connecting tubes, termed 'stolons.' However numerous the chambers are, they are originally formed by budding from a single one ; *i.e.* all Polythalamia have commenced life as Monothalamia. The shape of the shell depends upon the direction in which the first sarcode is added, and may be straight, spiral, circular, or radiating. The Foraminifera are the oldest of all animals in time, for amongst them is found the gigantic foraminifer, the Eozoon Canadense, found in the Laurentian rocks of Canada, which form the lowest of all the Palæozoic series.

To this order *Bathybius* is referred, which consists of a mass of sarcode lying in the bed of the sea with little bodies called coccoliths and coccospheres, enveloped in protoplasm, growing upon it.[1] Professor Häckel considers this to be the simplest of all organisms, and derives all the rest of the animal creation therefrom.

Order 4. **Radiolaria** are minute marine and fresh-water Protozoa, which only differ from Reticularia in the fact that their shell is always siliceous ; they contain the following families :—[2]

1. *Acanthometrina;* minute, marine, floating Radiolaria, with a garniture of siliceous hollow spines arranged circularly. The spines being hollow transmit the pseudopodia.

2. *Polycystina* are also marine and microscopic Protozoa, enclosed in a very beautiful and much perforated shell. The sarcode is of an olive colour.

3. *Thalassicollida* are masses of protoplasm, from an inch in size downwards, containing siliceous spicules, which float upon the surface of the sea, much as *Bathybius* floats at the bottom. Not unfrequently the Thalassicollida form colonies.

Class III. SPONGIDA constitute a large and important class of ~~Protozoa.~~

What we familiarly call a sponge is, in fact, the skeleton

[1] Coccoliths, according to the recent researches of Dr. Carter, are unicellular vegetables, allied to the Millipores, and would, in such case, seem to be the food of Bathybius.

[2] Some few, such as *Actinophrys*, have no shell or spicular armature whatever.

of a colony of Spongida. The so-called sponge is covered over with the gelatinous sarcode, which has, in the first place, secreted the *supporting* skeleton, and is pierced by numberless apertures, some small and very numerous, others large and fewer in number. The sea water passes in through the small apertures or 'pores,' and is then by ciliary action passed through every part of the sponge, and deprived of any floating organic materials it may contain, after which it is ejected through the large apertures or 'oscules.' In this way is a respiratory, circulatory, and digestive apparatus first sketched in the Animal Kingdom. It will also be seen from what is stated here, that the chief difference between Spongida and Rhizopoda is that the support is internal in the former, and external in the latter.

Reproduction is either asexual or sexual. First, *asexual reproduction.*

Take the common fresh-water sponge, *Spongilla*, by way of illustration. The deeper parts of this sponge develop gemmules, which are composed of an outer and an inner wall with cells, called *amphidiscs*, placed between the two. These gemmules increase in size, and form a depression at one part of the surface called the *hilum* or *micropyle*, through which the germs, which form within the gemmule, are expelled in the spring-time of the year. Escaped from the sac these germs become covered with cilia, and for a time swim freely about, but after a time steady down, as it were, and, glueing themselves to some foreign object, increase in size, but remain stationary for the rest of their lives. Second, *sexual reproduction*. In other Spongida, *e.g.* Tethea, certain sponge particles or 'sarcoids' become detached and nucleolated, so as to form ova, while others become molecular, and finally produce spermatozoids. The union of these two cells produces a ciliated freely moving embryo, which finally goes through the same stages as the young sponge described before.

The class of Spongida contains the three orders, Keratosa, Silicea, and Calcarea.

Order 1. **Keratosa**. In these the skeletal support is horny, and frequently supplemented by small siliceous spicules; in this order are the sponges of commerce, which derive their value from the fine texture of their horny hairs, and their entire absence of siliceous spicula.

2. **Silicea**. The skeleton is formed of flint-like spicules, which are sometimes woven or fused together. In this order is found the exquisite *Euplectella*, which forms a hollow lace-like skeleton, in the shape of a cornucopia: this is imbedded at its

lowest extremity in the oozy bed of the seas the sponge frequents, and there held in its place by the peculiar anchorate spicula, with which this extremity is furnished.

3. **Calcarea.** In these the skeleton is composed of carbonate of lime, *e.g. Grantia.*

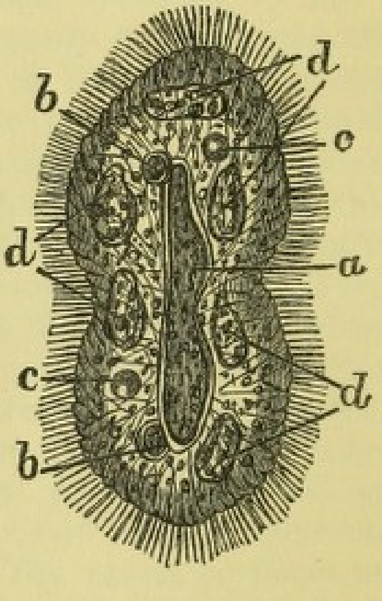
Sponges afford us the first good illustration of a compound animal, *i.e.* a number of animals whose individuality is still almost absolute, uniting to form a colony. The whole class is of great antiquity, being frequently found in the Palæozoic strata, and forming great masses of fossil rocks in the Mesozoic period.

CHAPTER V.

Infusoria—Physiology of Protozoa.

Class IV. INFUSORIA form the other great division of Protozoa characterised by the possession of an oral aperture. The Infusoria, named from the fact that they abound in any infusion of vegetable matter which is allowed to putrefy, are manifestly the most highly organised of all the Protozoa, and are sometimes elevated to the position of a distinct sub-kingdom.

Fig. 5.



An Infusorium (*Paramœcium bursarii*) highly magnified. *a.* Nucleus dividing. *b b.* Nucleoli. *c c.* Contractile spaces. *d d d.* Larger cavities, which being given off from the gullet of some Infusoria, constitute the so-called stomachs.

The body is unsymmetrical, as a rule ; but the sarcode is always surrounded by a firm envelope. The sarcode always contains a nucleus and nucleolus. The oral aperture is usually fringed with cilia, which move automatically, and act as respiratory and digestive agents. The contractile vesicles are numerous, and regularly arranged. None of these develop Pseudopodia. Three orders are generally recognised : Ciliata, Suctoria, and Flagellata.

Order 1. **Ciliata** is the most numerous order of Infusoria, comprising all the ciliated specimens : many also possess jointed bristles, called 'styles,' and hooks, or 'uncini.' Several families are found in this large order, of which the following are the chief :—

Paramœcium is a free fresh-water Infusorium, shaped like a tiny slipper, the hole for the foot being represented by the mouth which leads into the general mass of sarcode, or 'chyme mass.' The contractile vesicles which occupy the interior, keep up a sort of circulation of granules in the interior, and so remind one of a vascular apparatus. Besides these vesicles, the gullet, so to speak, constantly throws out little processes, which look like stomachs, and so give rise to the old term of *Polygastrica*. Reproduction is either by fission, or sexually, by the union of spermatozoa developed from the nucleolus, and of ova the product of the nucleus.

Vorticella is a fixed and stalked fresh-water Infusorium, abundant on the surface of aquatic plants. A single animalcule looks like a minute campanula ; the bell-like calyx being supported upon a stem, which is possessed of contractile power residing in the sarcode, and called the 'stem-muscle.' The disc at the top represents the mouth, and is fringed with cilia. Reproduction, (1) by fission, (2) by gemmation, each bud consisting of a prolongation of the chyme mass, surrounded by the two outer layers—and (3) by encystment.

Epistylis differs only from Vorticella in its stem being much branched, and non-contractile. It occurs on the stems of aquatic plants, and looks like a sort of mould. The cilia round the mouth are fixed to an outstanding rim, which is termed the 'peristoma.'

Stentor is a fresh-water Infusorium, with a calyx like the mouth of a trumpet. It is either free or attached ; when free, swimming by means of its cilia. On first observing its movements it appears to roll over and over, but this appearance is only caused by the action of the cilia.

Vaginicola possesses a horny cuticular case—the carapace, or 'lorica,' within which the animal can retire.[1]

Order 2. **Suctoria** consist of Infusoria possessing filaments which end in suctorial discs, which are prehensile organs, capable of protrusion and retraction. *Acineta* is a member of this order, but the fact that no mouth is discoverable makes it doubtful whether it should not be relegated to the Astomata. Some of the Suctoria contain chlorophyll.

Order 3. **Flagellata**. In these Infusoria locomotion is performed by long bristles, or flagellæ, which may be single, double, or multiple. The *Noctiluca* is the best known member of this order. It is a minute organism, but so vast in numbers that it is the chief source of the phosphorescence of the sea. To the naked eye, and even to the microscope, there is no surpassing beauty in them ; all that is seen is a simple sac with numerous

[1] Some of the lower forms (principally *Flagellatæ*) possess a bright red pigment spot; and in *Paramecium* certain curious cells, with thread-like appendages, protrudible at will, have been observed. These cells are the thread cells, or 'trichocysts,' and are probably endowed with some urticating property by the exercise of which the Infusoria are able to paralyse their prey.

vacuoles, some granular matter, an oral aperture, and a tail; but at night these little beings light up the ocean as with myriads of tiny lamps, and turn the waves to sheets of liquid fire. This power of emitting 'phosphorescence' is not well understood; it may be due to the oxidation of phosphorised fat, or it may be produced by the same causes which give rise to the Will o' the Wisp, which is now supposed to be produced by the formation of spontaneously inflammable phosphuretted hydrogen, generated by the decomposition of hypophosphite of calcium.

Physiological Processes of Protozoa.

From what has gone before, it is manifest that the sole function, besides locomotion and the power of reproduction, which the Protozoa possess, is that of digestion. The food, which often consists of a tinier organism than the diner, is absorbed into the general sarcodous mass; the digestible parts are absorbed, while the indigestible may be rejected through any part of the envelope that happens to be in propinquity with the morsel, though in a few there is a distinct aperture for the passage of excrementitious matters.

CHAPTER VI.

SUB-KINGDOM: CŒLENTERATA—CLASS: HYDROZOA.

CŒLENTERATA (κοῖλος, hollow; ἔντερον, intestine) comprise Polypes, Corals, Jelly fish, and Zoophytes.

Definition.—Aquatic animals, frequently resembling flowers in their general appearance. Substance of body soft and semi-transparent, surrounded by a denser envelope, which lines the continuation of the mouth and gullet, and clothes the exterior of the body; these layers are called the 'endoderm' and 'ectoderm.' The ectoderm, or integumental coat, contains little spaces in which the 'thread-cells' are situated; these cells possess an urticating property. There is a single opening which leads into the interior, which is called the somatic cavity; this opening serves both for mouth and anus This lined gullet and the thread-cells are, in fact, the distinctive peculiarities of the Cœlenterata. The nervous system, when discoverable, consists of a single ganglion, whence filaments radiate to all parts of the body.[1] The ganglion is placed opposite to the oral aperture. No organs of circulation exist; the mouth is surrounded by tentacles, which are never ciliated.

Cœlenterata are divided into two large classes, Hydrozoa and Actinozoa.

I. Hydrozoa have no digestive cavity distinct from the rest of the sarcodous mass forming the body, and their reproductive organs are external.

II. Actinozoa have a digestive canal distinct from the rest of the body, which is loosely suspended in the body sarcode by radiating membranous septa, the mesenteries, and their organs of reproduction are internal, placed on the so-called mesenteries.

Class I. HYDROZOA.

Order 1.	Hydroida .	1. Hydridæ 2. Corynidæ 3. Sertularidæ
,, 2.	Syphonophora	4. Calycophoridæ 5. Physophoridæ

[1] Dr. P. Martin Duncan's recent researches indicate that the Actinozoa possess a more highly developed nervous system than has yet been attributed to any Cœlenterates.

Class II. ACTINOZOA.

Order 1. Zoantharia
,, 2. Alcyonaria
,, 3. Rugosa
,, 4. Ctenophora

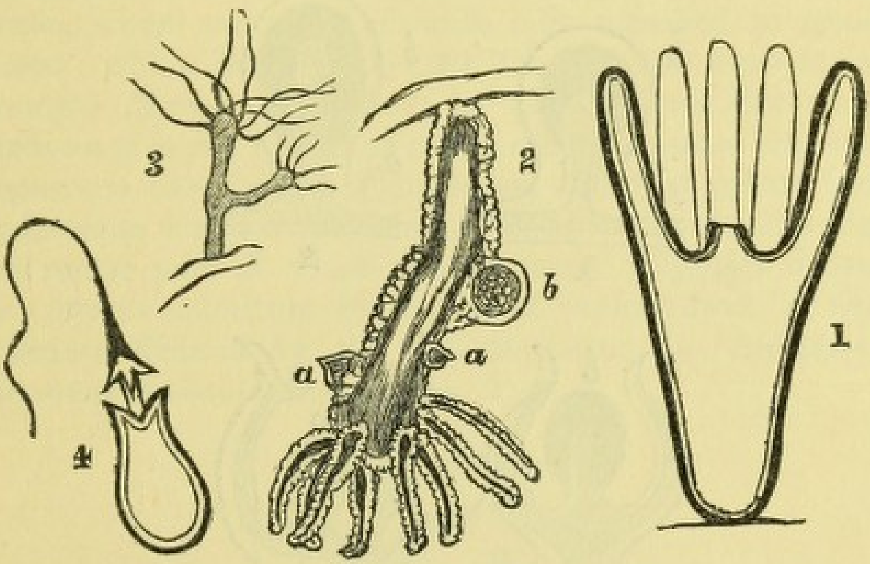
Class I. HYDROZOA. Order 1. **Hydroida.** Marine and fresh-water Hydrozoa, whose alimentary region, called 'polypite,' is provided with a disc, the 'hydrorhiza,' and whose mouth is surrounded by prehensile tentacles. The disc is generally attached to some foreign object; the body sarcode itself is termed 'hydrosoma.' Some of the Hydroida are free, but the greater number unite to form colonies. This large order comprises the fresh-water Hydridæ, most Medusæ or jelly fish, the Sertularians, and Corynids.

Hydra (comprising Hydra viridis and Hydra fusca) is the only genus of the Hydridæ; they are minute creatures, about a quarter of an inch in length, which are found attached by a disc to the under surface of aquatic plants, while their long tentacles float downwards in the water in search of prey. The attached end, or hydrorhiza, is the 'proximal,' the other free end is the 'distal' extremity, and is furnished with a tentaculated mouth; each of the tentacles is hollow, and is freely supplied with nematocysts, or thread-cells, which are the weapons with which the formidable little Hydra paralyses its victims. The organisation of the Hydra is very simple, as is proved by the circumstance that if one be divided into a dozen segments, each segment becomes a perfect Hydra. The Hydræ never, however, form colonies. If turned inside out, as has been done, the Hydræ get on equally well as before, and do not seem to mind their altered circumstances in the least. The body wall is formed of two membranes, one growing *out* the *ectoderm*, and one growing *in* the *endoderm*; the reproductive organs are placed beneath the former structure, and consist of sperm-cells with spermatozoa, and much larger germ-cells with ova; the contents of the two being liberated, produce offspring by sexual congress. Reproduction, however, often takes place by simple gemmation.

Corynidæ, or *Tubularidæ*, are marine minute fixed Hydrozoa, occasionally simple, but generally compound, whose individuals, when compound, are united by a common trunk, or *cœnosarc*: this common trunk is generally horny, which external horny coat is called the *polypary*. The reproductive organs vary in structure, and are variously developed from the sides of the body cavity, from the cœnosarc, or by germinal sacs, called 'gonophores,' from the body wall. The compound animal is formed by continuous budding; the buds remaining attached, forming a colony, all the individuals become connected with the living hollow stalk or cœnosarc, so that at last the compound animal looks like a little tree, all the branches of which are tubular, and which permit of the circulation of a nutrient fluid throughout the colony.

The reproduction of Corynidæ is so peculiar and important as to demand special attention—it is the first illustration which the Animal Kingdom affords of what is termed the alternation of generations. The generative buds of a Corynid may exist in

Fig. 6.

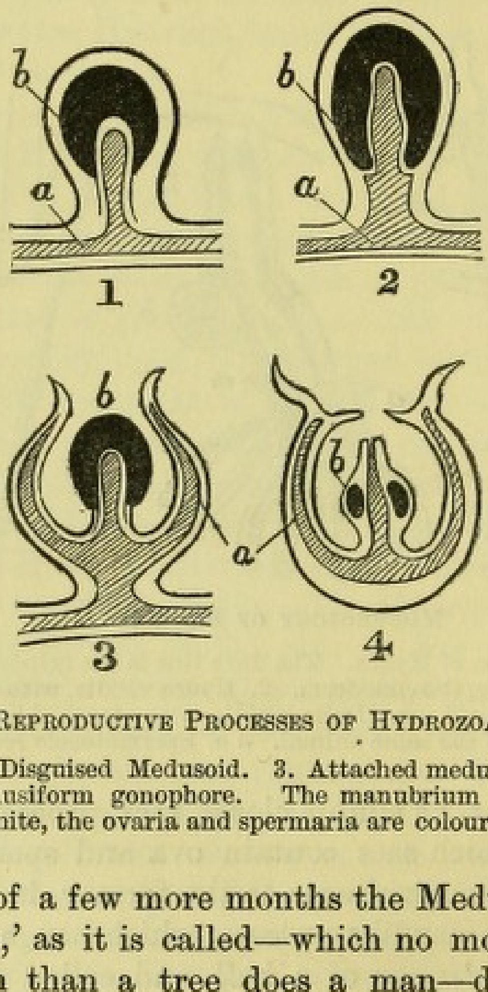


MORPHOLOGY OF HYDROZOA.

1. Diagrammatic section of Hydra. The dark line is the ectoderm, the fine line and clear space adjoining, the endoderm. 2. Hydra viridis, with two gemmæ budding out from the body wall. 3. Hydra viridis, with attached bud. 4. Greatly magnified thread-cell of the same animal. *a a*. Spermatozoic receptacles. *b*. Ovum.

various forms: 1st, as simple closed sacs, processes of ectoderm and endoderm, which sacs contain ova and spermatozoa; 2nd, as sacs with the same contents as the former, but also provided with a hollow hammer-like process, which hangs vertically from the roof like the clapper of a bell, and called the *manubrium* (fig. 7)—from this organ tubes are found to radiate over the entire surface of the sac; 3rd, as attached buds with an open mouth, and with a series of canals, both circular and radiating, called *gonocalycine* canals, which surround the walls and permit of a free circulation of fluid; and, 4th, as free buds, which are furnished with the same series of gonocalycine canals as the former variety. These free buds are by far the most interesting of all ; each is, in fact, an embryotic Corynid, it becomes ciliated, develops a mouth and tentacles, and swims freely about. This minute animal, called a Planula, measuring $\frac{1}{8}$-inch in diameter, grows rapidly ; its rays become short and disappear, while its oral tentacles and *nemato-cysts*, or *thread-cells*, make their appearance. After a month or two of this existence it increases enormously in size, the upper sac becomes a large gelatinous umbrella-like translucent covering, and its hollow tentacles droop as fringe into the sea. In this condition it constitutes an Acaleph, Medusa, or Jelly Fish (fig. 9), which is thus seen to be nothing but an intermediate stage of a Corynid Hydrozoon.

Fig. 7.



Reproductive Processes of Hydrozoa.

1. Sporosac. 2. Disguised Medusoid. 3. Attached medusiform gonophore. 4. Free medusiform gonophore. The manubrium and gonocalycine canals are white, the ovaria and spermaria are coloured black.

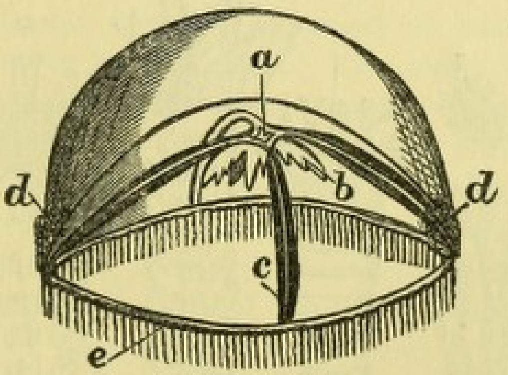
After the lapse of a few more months the Medusa, or 'Medusiform Gonophore,' as it is called—which no more resembles the parent organism than a tree does a man—develops its own sperm and germ-cells, which uniting produce a fixed Corynid once more, and thus the cycle of changes is completed. The entirety of the Hydrosoma is rapidly formed by budding from the single polyp. This description, though specially referring to the Corynida, applies with sufficient accuracy to the reproduction of the majority of the Hydroida (fig. 10).

All Acalephæ possess urticating organs, called *thread-cells*, which they can protrude and employ at pleasure. Their movements are effected by muscular contraction. The muscular fibres are very pale and indistinct, but are said to resemble the unstriped muscle of the human subject. The sense of sight makes its first appearance in the animal series in this group, in the shape of *eye-spots*. A nerve passes from the principal ganglion to some part of the ectoderm, where it expands into a nervous membrane, behind which we find a pigmentary tunic. This is the mode of construction of 'eye spots,' or 'ocelli,' wherever met with in the Animal Kingdom.

Organs of hearing, lithocysts, are also met with, placed at the base of the tentacles.

Those Medusæ which swim by the contraction of their umbrella-like disc were formerly called *Pulmogrades*; those, like Beröe, which swim by vibratile cilia attached to arms, *Ciliogrades*; while those which float like Physalia were termed *Hydrostatic Medusæ*. It must be remembered that while some Medusæ give rise to a fixed zooid, others produce free swimming organisms exactly like themselves, and that others produce a hydrosoma which is furnished with an umbrella-like disc, from the under part of which one or many polypites depend; the two former constitute the so-called 'naked-eyed,' or *Gymnophthalmate Medusæ* (fig. 8), and the latter the 'hidden-eyed' or *Steganophthalmate Medusæ* (fig. 9).

Fig. 8.

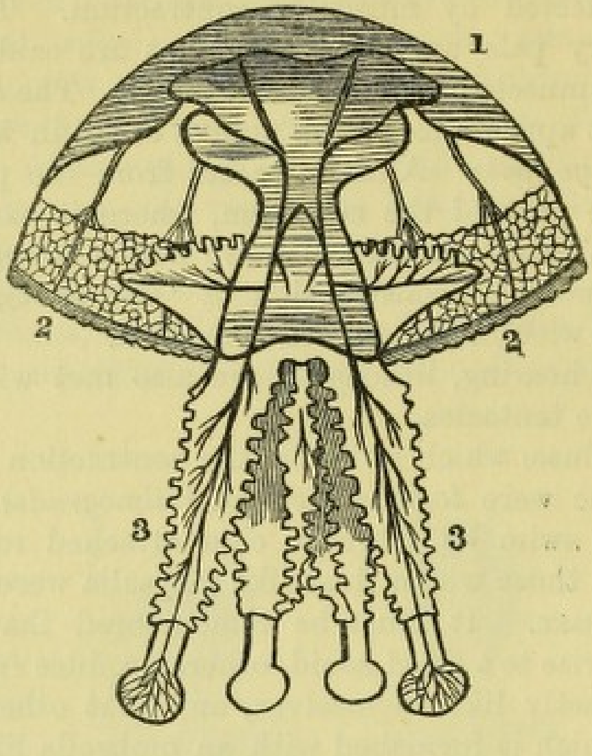


NAKED-EYED MEDUSA.

a. Stomach. *b*. Oral tentacula. *c*. Gonocalycine canals. *d d*. Ovaries *e*. Marginal Canals.

The Hydrosoma of the fixed and compound submarine Corynidæ is connected by a cœnosarc, and surrounded by a hard tubular polypary (whence their name Tubularidæ), through which the tentaculated polypites protrude. They cannot, however, be retracted beyond the open mouth of the polypary.

Fig. 9.



HIDDEN-EYED MEDUSA (Rhizostoma).

1. Umbrella. 2, 2. Circumferential and radiating inosculating canals. 3, 3. Stomatodendra with minute polypites attached. The figures 3, 3, are placed upon the fringed tentacles.

Fig. 10.

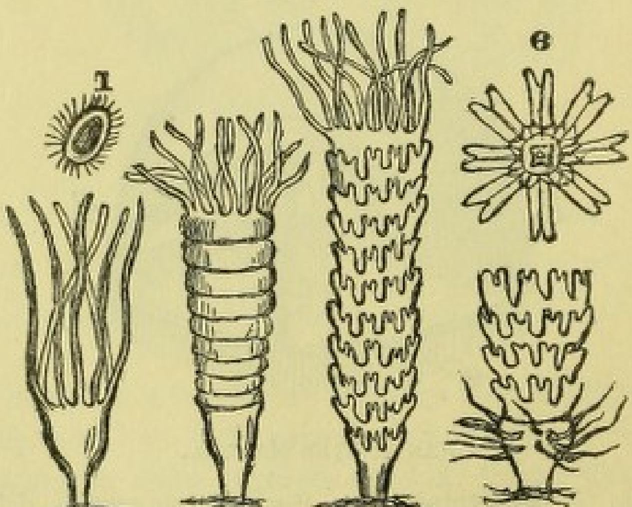


DIAGRAM ILLUSTRATIVE OF THE DEVELOPMENT OF HYDROZOA.

(The specimen is one of the Lucernaridæ.)

1. Ciliated embryo or 'planula.' 2. Hydra tuba, showing a single individual. 3. Hydra tuba undergoing segmentation. 4. The segmentation becoming more complete. 5. More advanced stage in which the tentacles are developed from the first or basal segment. 6. Segmentation complete, giving rise to a free swimming Medusoid.

Sometimes the tube is jointed with the tentacles placed in a whorl round each joint (*e.g.* Tubularidæ divisa), sometimes it is undivided (*e.g.* Tubularia indivisa). Sometimes the polypary is much branched (*e.g.* Eudendrium), at others it is not branched (*e.g.* in the majority of Tubularidæ); the polypary of the latter closely resembles small straws filled with a soft reddish cœnosarc. A few of the Corynidæ do not possess a hard polypary (*e.g.* Corymorpha nutans), but on the contrary only a soft white fleshy stem. Many of these are objects of the greatest beauty, as is the case with this very polyp, which forms a submarine colony about four inches in length.

Sertularidæ are fixed, compound, and generally branched marine Hydrozoa, with a firm chitinous polypary, which always expands at its extremity into little cups, called *hydrothecæ*, which contain and protect the polypites. They very closely resemble seaweed; in their reproduction they resemble Corynida, *i.e.* they go through an alternation of generations, one stage being the development of a medusiform gonophore, and indeed there does not appear to be sufficient reason to raise them into a distinct group. The entire colony is nourished by the combined action of the individual polypes; each separate branch of the seaweed-like creature is tubular, and leads into a canal which traverses the entire length of the main trunk, or cœnosarc, so that whatever passes the separate polypes must also traverse the supporting cœnosarc, a constant current of fluid being thus kept up by ciliary action.

Campanularidæ resemble Sertularidæ, except that the *hydrothecæ* are stalked and terminal, instead of being sessile and lateral, as they are in Sertularians. The name is derived from their bell-like appearance in early youth, when they are very gaily dressed and free in their habits. At this period the margins of the calyx are furnished with a beautiful fringe of tentacles, and the hollow *manubrium*, terminated by the mouth, hangs loose in the water, looking like a long pistil. The surface and rim of the bell are traversed by gonocalycine canals, which at another period of its existence correspond to tentacles. After a time it develops ova, *which grow up into the fixed colony from which it sprang.*

Order 2. **Siphonophora**, including Calycophoridæ and Physophoridæ, are free swimming or compound floating marine Hydrozoa, with an unbranched or only slightly branched, but muscular cœnosarc, the proximal end of which is provided with a muscular locomotive sac called *nectocalyx*, from which a sort of shelf runs inwards; it is often dilated. The nectocalyces are traversed by tubes called the nectocalycine canals. In reproduction the Siphonophora go through a similar alternation of generations to the former order.

The *Calycophoridæ* are free swimming Hydrozoa which abound in tropical seas ; the *Physophoridæ* including the *Physalia*, or Portuguese man-of-war, the *Velella* and *Porpita* are remarkable chiefly in the construction of their cœnosarc. In the Physalia it is a large bladder-like organ, the *pneumatophore*, or float, and serves to buoy up the entire hydrosoma ; in the Velella it forms a sort of permanent latteen sail, by which the wind drives it along the surface of the ocean. There is a cartilaginous body developed in the interior.

Besides the above orders, certain fossil organisms called *Graptolites* frequently found in the Silurian rocks, are now generally collated with the Hydrozoa.

Many of the marine Hydrozoa are phosphorescent.

CHAPTER VII.

Class: Actinozoa—Construction of Coral Reefs—Physiology of Cœlenterata.

Class II. ACTINOZOA, comprising the corals and sea anemones, occupy a large area both in space and time, being found in every part of the world, and extending from the Palæozoic period to the present time. They are either free or fixed, simple or compound, marine Cœlenterates, with a digestive cavity separated from the general somatic cavity by a perivisceral space, which space is subdivided into loculi by vascular membranous septa called mesenteries, upon which are found the organs of reproduction, and which reach from the digestive tube to the body wall everywhere except directly below the stomach, where the loculi communicate. If therefore a transverse section be made of an Actinozoon, it would somewhat resemble a cartwheel : the axle being the digestive cavity, the spokes answering to the mesenteries, and the outer tire corresponding to the ectoderm. The ectoderm is more highly developed than in Hydrozoa, presenting indeed the elements of derm and epiderm met with in the skin of higher animals. Cilia are present on the digestive tube. The tentacles are hollow, and perforated at their extremity. Reproduction is either sexual or gemmiparous in character. As in Hydrozoa the entire animal is termed Hydrosoma, so in this class it is styled *Actinosoma,* the connecting stalk being still called *cœnosarc,* and the individual actinozoa, *polypes.* The Actinozoa are very muscular, both mesenteries and body walls being supplied with distinct sets of muscles.

Actinozoa contain four orders, Zoantharia, Alcyonaria, Rugosa, and Ctenophora.

Order 1. **Zoantharia** is a large order, including the soft-skinned sea anemones, and the greater number of the stony corals. They are supplied with numerous simple oral tentacles, and the mesenteries (and coralline septa when present) are disposed in multiples of five or six.

The Zoantharia are broken up into three great divisions :—Malacodermata, Sclerobasica, and Sclerodermica.

The *Zoantharia malacodermata* form the very natural group of soft-skinned Actiniæ which are common objects in every marine aquarium. A sea anemone is composed of a soft vertical cylinder, the *column*, an attached end, the *base*, and a tentaculated mouth at the upper end, the *disc*. The tentacles, which sometimes number as many as 200, are prehensile organs, and are all perfectly retractile within the ectoderm. The mouth is also surrounded with cilia, which keep up a constant current of water, and so bring nourishment to the support of the organism. Most Actiniæ are diœcious, one possessing only ova, and another only spermatozoa.

Zoantharia malacodermata contain the following families :—

1. Actinidæ. Polypes destitute of a corallum, with a body shaped like a short truncated cone, with a broad base, and numerous tentacles around the disc. The embryos of Actinidæ are free, and the mature forms are capable of locomotion.

Fig. 11.

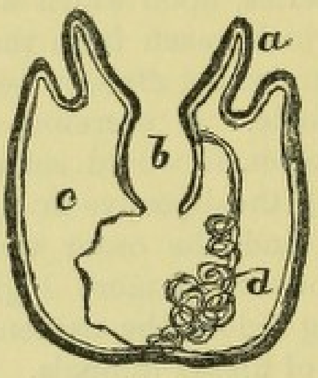


Diagram to show the Morphology of Actinozoa.

a. Tentacle non-ciliated. *b*. Mouth leading to the Stomach Sac. *c*. Mesentery which supports the generative organs, *d*.

2. Ilyanthidæ. Soft-skinned Polypes with a pointed base.

3. Zoanthidæ. Polypes possessing a rudimentary spicular corallum, and unlike the two former families in being connected at their bases by a fleshy cœnosarc.

The *Zoantharia sclerobasica,* the second subdivision of Zoantharia, include certain smooth-surfaced corals, such as the Black Coral, *Antipathes.* The coral of this group is secreted by the outer layer of the *inverted* ectoderm, and is therefore a true exoskeleton, like the shell of a lobster.

The *Zoantharia sclerodermica,* which form the third subdivision, on the contrary, include all the rough cupped corals, such as Madrepores, and in them the coral is secreted by the inner tissues of the body. The former are always compound, the coralline cœnosarc forming the bond of union ; the latter may be either single or compound, each individual when compound representing in section a fossil actinia, with body cavity, mesenteries, and perivisceral space *in situ*. Coral is composed chiefly of carbonate of lime, but is occasionally horny, or it may be a mixture of the two.

The Sclerobasic and Sclerodermic corals contain the following families :—

A. Sclerobasic corals.

1. *Antipathidæ*, branched sclerobasic corals, whose individual polypes are always provided with mixed tentacles.

B. Sclerodermic corals.

1. *Tabulata*. The septa, which are vertical divisions of the calcified mesenteries, are rudimentary, but the mesenteries themselves are perfectly developed.

2. *Perforata* ; the septa are well developed, but the mesenteries are absent.

3. *Aporosa* ; the septa well developed ; no mesenteries ; coral very hard and compact.

4. *Tubulosa* ; rudimentary septa ; the coral cups or thecæ are pear-shaped.

Reproduction in all these Actinozoa is by fission or gemmation ; alternation of generation never occurs.

Order 2. **Alcyonaria,** comprising the asteroid polypes, are, as a rule, compound Actinozoa, generally possessing a coralline skeleton, and whose mesenteries are in multiples of four. The tentacles, eight in number, are always minutely fringed or feathered. Many of the members of this order resemble fossil fronds of ferns. The order is broken up into the four families, *Alcyonidæ*, *Tubiporidæ*, *Pennatulidæ*, and *Gorgonidæ*.

1. *Alcyonidæ* are fixed compound corals, with a sclerodermic cœnosarc composed of scattered granules. Type-form, *Alcyonium*, or dead men's fingers, a sponge-like, yellow compound Actinozoon, fixed to some submarine object. The little polypes are projected through minute apertures in the coral and retracted at will.

2. *Tubiporidæ* are compound sclerodermic corals, without septa, but provided with cups or thecæ. Type-form, *Tubipora musica*, or organ-pipe coral, a mass of bright red coral, formed by a great number of vertical tiers of hollow tubes, in the upper ones of which the little green polypes dwell, and through which they protrude themselves in search of food.

3. *Pennatulidæ*, or sea pens, are compound sclerobasic corals, with eight tentacles. Type-form *Pennatula*, or cock's comb,

an Actinozoon about four inches long, found at the bottom of muddy seas. The attached end of the cœnosarc is smooth and fleshy, the upper end is fringed with feather-like pinnæ. The cœnosarc is yellow, the disc end reddish purple.

4. *Gorgonidæ*, sea shrubs or fans, are fixed compound sclerobasic corals, whose cœnosarc is grooved and finely branched. The tentacles are always eight in number. Type-form, *Corallium rubrum*, or red coral. Corallum, or Sclerobase, smooth, bright red, calcareous, and much branched. Cœnosarc, the soft investing membrane, dirty white, or flesh colour. *The cœnosarc invests a very similar, jointed, and slightly grooved sclerobasis;* along the cœnosarc are placed the apertures for the protrusion of the little eight-tentacled polypes. The cœnosarc is channelled by numerous tubes, which contain the so-called 'milk' for the nourishment of the entire colony.

Order 3, **Rugosa,** is an order of entirely extinct Actinozoa, chiefly found in the Palæozoic strata. They were simple compound sclerodermic corals, with *thecæ*, *tabulæ* and *mesenteries*, which are soft, membranous partitions in which the *septa* are secreted. The tentacles were in multiples of four. The thecæ appear in some instances to have been furnished with an operculum or lid; examples, *Calceola*, *Goniophyllum*, and *Cystiphyllum*.

Order 4. **Ctenophora** (κτείς, a comb; φέρω, I bear), soft, free, simple, transparent marine Actinozoa, whose organs of locomotion consist of ciliated parallel rows of bands or paddles, called 'ctenophores.' Type-form, *Pleurobrachia*.

The Ctenophora are the most highly organised of the Actinozoa; in them for the first time a nervous system is clearly traceable. It consists of a ganglionic mass at the upper end, or 'apical' pole of the animal, whence nervous filaments radiate to every part of the body. *Pleurobrachia* is a little balloon-like creature, with a mouth at the lower, or 'oral' end, and a rounded surface at the upper, or 'apical' pole; the body between these extremities is called 'interpolar.' Eight long wavy arms, fringed with cilia, are placed at equal intervals, by the movements of which 'ctenophores' the animal progresses. The internal structure is somewhat complex: the mouth leads first into a stomach, and thence into a second lower and larger dilatation or 'funnel,' from which two passages lead to open (anal like) at the apical pole. Tubes radiate from the funnel, and communicate with a peripheral channel, which girdles the entire circumference; along these ducts fluid is constantly kept circulating by the action of vibratile cilia; the chief differences between the families of Ctenophora consist in the various modes in which this canal system is arranged. At the apical pole may be seen the 'ctenocyst,' a small organ consisting of a vesicle containing minute sandy particles. This 'ctenocyst' is close to the ganglionic centre, and is believed to be an organ of hearing.

Families. 1. *Callymidæ.* The mouth occupies a portion only of the oral pole; a single pair of oral lobes are present. The tentacles are numerous, and turned towards the mouth.

2. *Cestidæ* (Venus's Girdle). The body is flattened and lengthened out to perhaps four feet; it bears two ctenophores, with two tentacles turned towards the mouth.

3. *Callianiridæ.* The body has long lateral lobes, with ctenophores; the tentacles are turned from the mouth.

4. *Pleurobrachiadæ.* No oral lobes; body balloon like; tentacles turned from the mouth.

5. *Beröidæ.* The mouth occupies the whole of the oral pole; no oral lobes and no tentacles.

The work of the coral-building Cœlenterates is in itself so interesting as to demand a brief notice. It is found that the Actinozoa engaged in producing coral reefs cannot live above the water level, exposure to the sun soon killing them; again, they cannot exist at a depth of more than thirty fathoms, and yet coral reefs are constantly met with as much as three hundred fathoms in thickness: this apparent paradox being due to the fact that the land where coral reefs are forming is constantly *subsiding,* fresh living corals ever taking the place of the dead ones: at the same time, the sea breaking upon the edges of the reef perpetually chips off and heaps up fragments of rock *above* the water level.[1] Constant subsidence and continuous superficial growth are thus going on *pari passu.* If the centre of a reef sinks more quickly than the sides, a lagoon is left, surrounded by a circular reef of coral; this is called an 'atoll;' if an island rises in the middle of this lagoon, a 'barrier reef' is said to be formed; while if the sea clearly intervenes between the reef and the mainland we have what is termed a 'fringing reef.' Different varieties of Actinozoa build these reefs: Madrepores, Millepores, and Gorgonidæ work chiefly at the top; below them we meet with Meandrinas (Brain coral); and lowest of all the work is done by Astræans.

The following are some of the more important terms employed in describing the morphology of Actinozoa:—*cœnenchyma,* the skeleton of the cœnosarc; *theca,* the skeleton of the body wall; *Columella,* the base skeleton; *septa,* and *pali,* the mesen-

[1] Other corals, though not reef-builders, are found at the greatest depth yet fathomed.

teries; *dissepiments*, regular transverse plates joining septa; *synapticulæ*, irregular and oblong plates, joining septa; *costæ*, external vertical ridges.

Physiological Processes of Cœlenterata.

Briefly reviewing the principal physiological processes of the Cœlenterates, we find a decided advance upon the Protozoa.

Digestion is still effected by the body cavity in a great measure, but this is combined with a stomach of some size, and provided with a membrane, which secretes a digestive fluid, and containing at its lower end an aggregation of cells supposed to be of a hepatic nature; it is remarkable, however, that if a cœlenterate be turned inside out, the ectoderm becoming the endoderm, absorbs and digests as perfectly as if nothing unusual had happened, as was seen to be the case with the Hydra. In the compound cœlenterates the lower part of the body cavity communicates with a tube in the cœnosarc, which is common to the entire colony.

Although no organs are specialised for *circulation*, yet a constant current, which is both respiratory and circulatory in function, is kept up in the perivisceral space and in the body cavity by the action of vibratile cilia.

A *Nervous system* is often detectible, and when this is the case it is composed of a ganglion placed near the mouth, whence filaments of nerves radiate to the integuments and muscles of the animal's body.

Locomotion is chiefly effected by muscular action, and is no longer solely ciliary, the muscles being disposed in transverse and longitudinal bands beneath the ectoderm; they are of the unstriped variety.

Senses.—*Ocelli*, or *eye-spots*, are present in most Hydrozoa and some Actinozoa; they are simple prolongations of a nerve which is derived from the single ganglion, and which expands behind a pigmentary tunic. *Lithocysts*, or *ear-sacs*, are also often present in similar communication with the nervous ganglion; they consist of a small sac filled with fluid, and perhaps containing a little calcareous matter, which may increase the vibrations of sound.

Reproduction has been sufficiently described; it is chiefly remarkable for the alternation of generations which is so common among the members of this sub-kingdom.

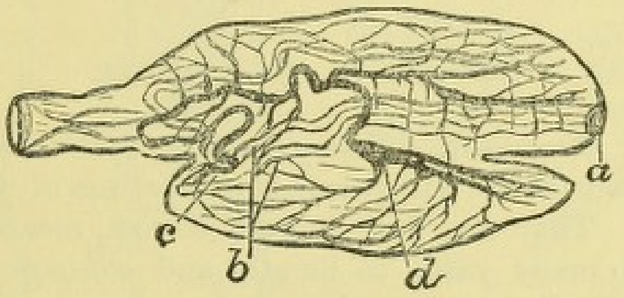
CHAPTER VIII.

SUB-KINGDOM: ANNULOIDA.—CLASS: SCOLECIDA, WITH ITS ORDERS.

Annuloida comprise Scolecida and Echinodermata. The former embraces the old class of *Entozoa*, or parasitic worms.

Definition.—The distinguishing feature of Annuloida is the possession of a set of canals, which constitute the 'water-vascular system,' and differ from the vessels of all other animals.

Fig. 12.



ANNULOIDA.

Diagrammatic section of *Aspidogaster conchicola*, to show the water-vascular system. *a*. Terminal pore. *b*. Lateral contractile vessels. *c*. Lateral ciliated trunks. *d*. Dilatation of trunks.

A true vascular system is also sometimes present. A nervous system is constant, composed of an oral ganglion and radiating filaments. The alimentary canal is distinct from the body cavity, and furnished with both oral and anal apertures. The Annuloida are never compound animals, in the sense in which Actinozoa and Hydrozoa are compound; they are always free, and frequently exhibit an alternation of generations in their reproduction.

Annuloida contain two Classes: Scolecida and Echinodermata, which possess little in common except a water-vascular system.

Class I. SCOLECIDA (σκώληξ, a worm). All the Scolecida possess a complete water-vascular system. The greater part of them are parasitic, and develop by alternation of generations. They comprise the majority of parasitic worms, both round and flat, and the Rotifers, or wheel animalcules. They are not radially, but often are linearly, symmetrical. The water-vascular canals open by tubes upon the exterior, and branch freely in the interior. The Rotifers stand alone, and are here ranked as a sub-class; but the rest of the Scolecida are primarily divided into *Platyelmia* (flat worms) and *Nematelmia* (round worms). The whole class comprises the following orders :—

Class, SCOLECIDA.	*Orders.*
Sub-class Platyelmia	1. Tæniada 2. Trematoda 3. Turbellaria
Sub-class Nematelmia	1. Acanthocephala 2. Gordiacea 3. Nematoidea
Sub-class Rotifera	1. Wheel animalcules

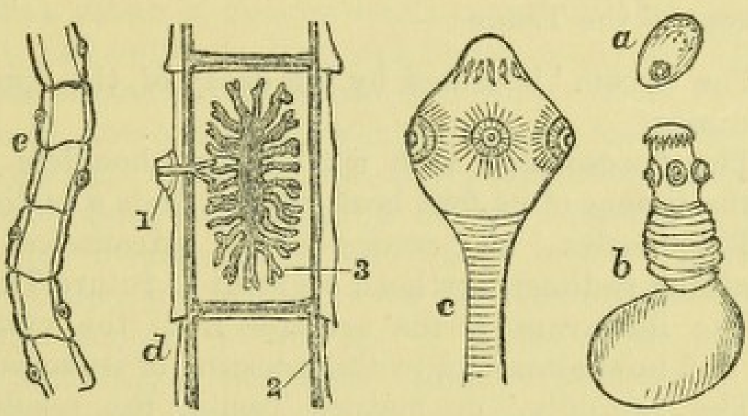
Sub-class I. PLATYELMIA.

Order 1. **Tæniada.** Tapeworms or Cestoid worms.

The tapeworms are parasitic in the intestines of warm-blooded vertebrates. They are flat, jointed worms, measuring from a few inches to many yards in length, and composed of a head, which is the real animal, and a great number of segments or proglottides, which are merely reproductive elements. The head is provided with suckers, hooks, or foliaceous appendages, by means of which the worm moors itself to the mucous membrane of its host; it feeds by imbibition (osmosis), there being no mouth or alimentary canal. Each segment contains male and female organs, with sperm and germ cells; and a set of lateral tubes, connected by an inferior transverse canal, which constitute the water-vascular system. The segments are continuously formed from the head, so that the tail segments are the oldest and the cephalic segments the most recent. The male and female cells escape by a common tube placed in the middle of each lateral half of a segment, the open pore being called the 'generative pore.' *Reproduction* affords an excellent illustration of the alternation of generations. The proglottides, together with the ova formed by the congress of the contiguous sperm and germ cells, are extruded from the intestine of the host. The proglottides decay, and give exit to their contained ova, each segment being thus capable of generating a vast number of ova, and the amount of segments thrown off being also very considerable. It follows that a full-grown tapeworm must be the parent of an almost innumerable offspring. The consideration, however, of the numerous vicissitudes through which these creatures must pass in their various phases of existence before attaining their mature condition, indicates a fortunate provision of nature for preventing their multiplication to a degree dangerous to the higher animals which they select as their hosts.

For convenience of description we may divide the life cycle of Tænia into six different stages. First, on looking at the mature proglottides discharged 'per anum' from the host, we see that the fertilised ova are set free by the decomposition of the walls of the segment; and that each ovum thus liberated

Fig. 13.



SCOLECIDA.

Morphology of Tæniada. *a*. Ovum with contained embryo. *b*. *Cysticercus longicollis*. *c*. Head of *Tænia solium* (enlarged): the circlet of hooklets is at the top, and below them are those of the cephalic suckers. *d*. A single segment or proglottis magnified. 1 Generating pore. 2. Water vessels. 3. Dentritic ovary. *e*. Portion of tapeworm, natural size, showing the alternating arrangement of the generative pores.

becomes covered with a dense envelope, which effectually protects it from wind or weather. It is now necessary for its further development, that it should be swallowed by some bird or mammal, and its case dissolved either by mastication or the gastric juice. The once more liberated ovum, now termed a 'proscolex,' is seen to be armed at one point by six siliceous hooklets. With these weapons it forces itself through the gastric walls, and takes up its abode in the liver or some other equally rich feeding ground. Having come to an anchor, it develops around itself a cyst containing fluid, and is now termed the 'scolex,' or 'resting larva' of the Tænia. Many creatures formerly known as 'cystic worms,' have now been discovered to be merely transitionary stages of various Tæniæ.

In this condition the creature is likely to remain for a long period, no further development being possible until the 'scolex' be liberated from its fleshy prison. This liberation is effected by the flesh containing the scolex being eaten by some other warm-blooded vertebrate. It is then able to complete its cycle of transformations. Having thus gained access to the intestine of its second host, its envelope is again dissolved by the process of digestion, and the now free 'scolex-embryo' fixes itself to the mucous wall of the alimentary canal by hooks and suckers which it has developed. The creature now begins to develop segment after segment of reproductive plates from the hinder part of the cephalic segment, each portion being termed a proglottis, becoming gradually sexually mature, and capable in its turn of producing fertilised ova. Subjoined is a table of the six stages of the development of the Tænia:—

(1) The 'ovum' liberated by the decay of the 'proglottis,' which contains

(2) The 'proscolex,' with six siliceous hooklets for perforating the tissues of its first host, until it finds a resting-place.

(3) The 'scolex,' or 'resting-larva,' surrounded by cyst, and containing rudimentary head segment of future Tænia.

(4) The immature Tænia set free from the cyst of the 'scolex,' and now contained in the intestine of its second host.

(5) The 'strobila,' or mature Tænia, the result of the development of the last stage, and going on to produce

(6) The 'proglottides,' or segments, in a state of sexual maturity containing fertilised ova.

The tapeworms commonly infesting man, viz., *Tænia solium* and *Tænia mediocanellata*, are derived respectively from the 'scolices' of the pig and the ox; the animals so affected being 'measled,' in common parlance. Man himself is attacked by a scolex—i.e., a parasitic worm in a transition state—which is called a hydatid cyst; this cyst contains an immature worm with cephalic suckers and hooklets, and if swallowed by a dog becomes developed into the *Tænia Echinococci*, which infests that animal. In like manner the tapeworm of the cat, *Tænia crassicollis*, is the adult form of the cystic worm of the mouse, *Cysticercus fasciolaris;* the tapeworm of the fox, *Tænia pisiformis*, the adult form of *Cysticercus pisiformis*, of hares and rabbits; the tapeworm of the dog, *Tænia serrata*, the adult form of *Cœnurus cerebralis*, the cystic worm which produces 'staggers' in the sheep.

Order 2. **Trematoda**; the flukes. They are flat or roundish Scolecida, infesting the intestines of vertebrates, especially fishes and birds. The intestine is much branched, and, as in Cœlenterata, there is but a single opening, which serves for both mouth and anus. There are suckers at the anterior end of the disc. They are diœcious, and in reproduction go through an alternation of generations. The *Distoma hepaticum*, or liver fluke of the sheep, may be taken as the type form. This is a flat ovate worm, a quarter of an inch long, with a sucker at either end. The 'genital pore' is placed laterally, midway between the suckers. The nervous system possesses a nervous collar, which surrounds the œsophagus, and whence nerves radiate to the various tissues.

There are distinct sets of muscles, which are agents in locomotion, beneath the integument, as is the case in most of the intestinal worms. The organs of reproduction are very large; indeed they attain a greater relative size in this class than in any other, and only one kind are found in any one Trematode. The female organs consist of the following: 1. A sub-globular *ovary* placed just behind the ventral sucker, and filled with nucleated cells; 2. *Vitellaria*, which are branched tubes, and are the yelk-supplying organs; 3. A *Uterus*, which is an expanded part of the ovarian duct, whence a *vagina* opens into a common cloaca; the ova acquire a shell-covering in the oviduct in the same manner as the egg of a bird. The male organs are: (1) A *Testis*, a convoluted tube, with cæcal diverticula, whence (2) A duct passes, the *vas deferens*, to open into (3) The *sac of the penis*. The life history of a Trematode is as follows: The product of the egg is a ciliated, freely swimming creature, furnished with ocelli, and called a *Monostoma*. This embryo becoming stationary, sheds its outer covering, and sets free a contained cyst, which is termed a *cercaria cyst*, *redia*, or *sporocyst*; it has two lateral appendages, and a tail. The sucker at the oral end increases in size, and the body is found to contain numerous little caudate bodies, which increase by fission, and are called *cercariæ*. These little bodies infest the bodies of fresh-water snails. Cercariæ are set free by rupture of the cyst. The little creatures now develop a sucker, boring spikes, and a water-vascular system, but no reproductive organs. In this state it swims about until it enters the body of a snail, or some such animal, by boring with its sucker. When safely housed, it casts off its tail and becomes encysted. Further changes only take place when the cyst is swallowed by a vertebrate, when it completes its final change by becoming a fluke.

Order 3. **Turbellaria.** Non-parasitic worms, which live in water, or else on moist land. The integument is ciliated, but there are no oral or anal suctorial discs. Unlike Trematoda, the Turbellaria have frequently no perivisceral cavity, the alimentary canal ending in the body sarcode.

They contain the *Planarida* and *Nemertida*.

Planarida are salt- or fresh-water Scolecida, with a protrudible net-like organ near the mouth, called the *proboscis.* They are generally *aproctous*, *i.e.*, without a separate anus. They are diœcious, and their reproduction is by fission, gemmation, or by congress of sperm and germ cells. Type-form, *Planaria lactea.*

Nemertida are marine and fresh-water worms; they possess a perivisceral space, a mouth, and distinct anus. They are ribbon-shaped, and in reproduction resemble Planaria. The larva of a Nemertis is called *Pilidium;* it is a small, helmet-shaped, freely swimming embryo, with the alimentary canal opening between the lobes. The adult Nemertis grows from a blastema thrown out from the sides of the alimentary canal.

Sub-class II. NEMATELMIA.—Parasitic Scolecida, with an elongated cylindrical body, without any differentiated locomotive organs, but with an appearance, it is nothing more, of segmentation. The Nematelmia are unisexual, and comprise some of the most formidable of the parasitic worms. The Acanthocephala, Gordiacea, and Nematoda are found in this division.

Order 1, **Acanthocephala,** are dangerous parasites, infesting fish and birds. They are very lowly in organisation, as are so many of this singular class; the simplicity of their structure indeed is not unfrequently as extreme as that of Protozoa, a circumstance that does not seem unimportant when we are treating of evolution. Many sub-kingdoms indeed possess in their ranks creatures of so humble a type as to render it unnecessary to travel much beyond them for their prototype. These Acanthocephala for example possess no alimentary canal whatever, and subsist, like the Tæniæ, entirely by a process of absorption. They are like the Tæniæ also in possessing a head, armed with suckers, by means of which they adhere to the intestine of their host; and in a third particular, viz., in the fact that they are developed through an alternation of generations from cystic worms, they remind us of the tapeworms.

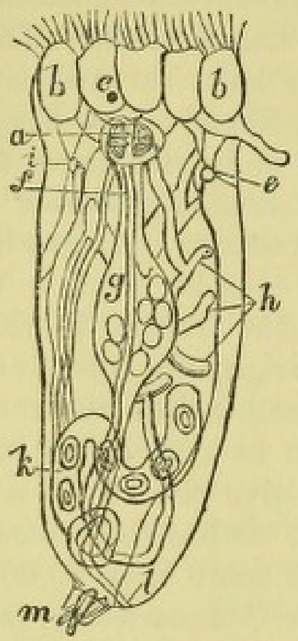
Order 2, **Gordiacea,** are hair-like parasites infesting grasshoppers and other insects, and often many times exceeding their victimized hosts in length.

Order 3.—**Nematoidea.** Thread worms, or round worms.

Free and parasitic worms, which often infest the human intestine; they comprise *Ascarides, Tricocephalus dispar* (infesting lower part of small and upper part of large intestine), *Oxyuris vermicularis* (found in rectum), *Strongylus* (found in liver, lungs, and kidneys), *Anclystomum duodenale* (found in the duodenum), *Filaria medinensis*, or Guinea-worm (in subcutaneous tissues), and *Trichina spiralis* (found in the muscles). The intestine is 'aproctous.' The integuments have three layers—1. epidermic; 2. muscular (of decussating fibres); 3. a deep cellulo-granular layer. Mouth at anterior end, with three fleshy lips, but no suckers, &c. Reproductive organs resemble those of Turbellaria. No alternation of generations. Males smaller than females. *Trichinæ* are encysted in muscles of pig. When eaten by man the cyst is ruptured, and the liberated Trichinæ increase enormously in numbers by viviparous reproduction, and emigrate from the stomach and intestines into the muscles. When they reach the muscles they again become encysted and quiescent, but during their march they give rise to the serious and often fatal symptoms of Trichiniasis. It has been calculated that individuals so affected have lodged more than 20,000,000 of these worms. *Filaria medinensis*, or Guinea-worm, is another parasite of importance as a cause of disease. The parent worm inhabits the tanks in India, and makes its way when very minute into the subcutaneous tissues of bathers. It lives and grows here for about a year, when, having attained a length of several feet, it again makes its way to the surface to get rid of its young. It is in this outward-bound passage that it gives rise to most distressing symptoms. The natives endeavour to extract it by twisting it slowly day by day round a little stick or twig, but if this once breaks, the injured animal retires beneath the skin, and the last stage of that man is worse than the first. It is a curious fact that all the known specimens of Filaria are adult females. There is another large division of Nematoid worms, comprising indeed more than 200 species, which are always free, and inhabit our ponds and seas. The most familiar example of this section are the *vinegar eels*, and the *vibrios*, which give rise to the 'purples' upon the ears of wheat. The generic name for this section is *Anguillulidæ*. They resemble the parasitic Nematoda in their anatomy.

Sub-class III. Rotifera. Wheel Animalcules. Free, minute, nearly all microscopic aquatic Annuloida, possessing well-defined water-vessels, which seem to act as excretory (urinary) and respiratory organs. The single opening of this system is at the hinder part of the body; tubes (ciliated) ramify thence through the body, and, after communicating with a large rhythmically contractile sac, terminate in the *trochal disc*. This ciliated cephalic, or trochal disc, called the 'wheel organ,' is capable of rapid inversion and eversion, giving rise to the wheel-like movements characteristic of these animals. This is the organ of locomotion (subservient also for collecting food), and acts much in the manner of a propeller to a screw. Sexes distinct. Males very small, and no alimentary canal. Females provided with complete alimentary canal. The free Rotifera have a 'foot,' or prehensile disc at the proximal or caudal end, and a pair of 'toes,' which act as pincers.

Fig. 14.



ROTIFERA.

a. Depression leading to mouth. *b b.* Trochal disc. *e.* Nervous ganglion. *f.* Pharynx with dentary apparatus. *g.* Stomach. *h.* Water-vascular system. *k.* Intestine. *m.* Cloacæ.

The mouth of a Rotifer is an elaborate machine, and consists of a lower jaw, which is fixed, but has two movable 'rami' connected with it, and upper jaws, or 'mallei,' which are also movable, and whose shear-like cutting edges divide the minute organic atoms on which the creatures prey. The mouth opens into a bulbous, muscular, walled pharynx, and thence leads to a simple, somewhat convoluted tube, which ends in a cloaca, common to the urinary, digestive, and generative organs. The cephalic nervous ganglion is very large in proportion to the size of the animal. They appear possessed of instinct to a considerable degree; indeed, they seem to possess many points in common with the class Insecta, although there are other features which connect them with Crustacea, and again others with Infusoria. The best hunting-grounds for Rotifera are the little pools in leaden pipes or tubes which are open to the air, or vegetable infusions after the smaller Protozoa have passed away.

CHAPTER IX.

Sub-Kingdom : Annuloida—Class : Echinodermata—Physiology of Annuloida.

Class II. ECHINODERMATA (ἐχῖνος, an urchin ; δέρμα, skin) form one of the best marked classes in the Animal Kingdom. These animals assume a variety of shapes ; they may be stellate or disc-shaped, spheroidal or vermiform, and unite with a radiate and generally quinque-partite arrangement, indications of being bilaterally symmetrical, always to be seen during the process of development, and frequently in the mature animal. They all possess a more or less perfect calcareous framework. The water-vascular system, which is common to them and the Scolecida, opens upon the exterior, subserves locomotion, and is termed the ambulacral system. The nervous system consists of a cord arranged in the form of a pentagon, surrounding the commencement of the œsophagus, immediately below the water-vascular ring. At each angle of the pentagon is situated a ganglion, from which proceed a long and a short branch ; the long branch, turning upwards, follows the curve of the shell, gives branches to ambulacral areas, and terminates in a ganglionic enlargement at the anus ; the short branch goes direct to the Lantern of Aristotle. Alternation of generations cannot be said to exist in the Echinodermata, the term Metamorphosis such as takes place in Lepidoptera, being more applicable to the changes which take place during the lives of these animals. The embryo is a free-swimming ciliated creature, strangely like a painter's easel, and hence called a *Pluteus.* This passes through a curious cycle of changes ; the digestive canal appears in the middle of the frame, and makes a ventral curve, or a curve towards the digestive canal. Contemporaneously with the disappearance of the frame of the Pluteus, the future Echinus becomes sketched in, and a radially symmetrical animal at length results, which is totally unlike its predecessor.

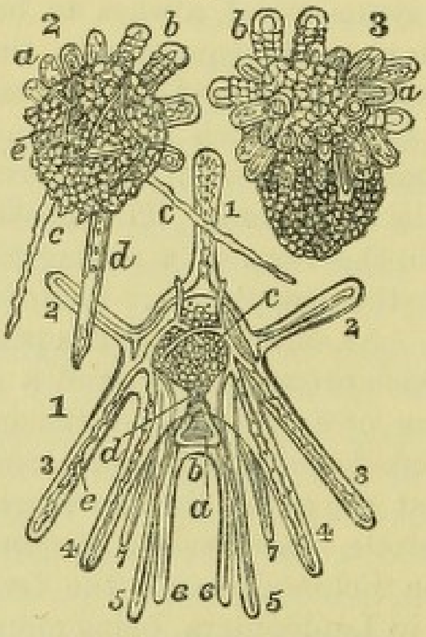
The Echinodermata are interesting in affording striking examples of the different directions in which evolution may tend, *e.g.* taking an Echinus, or Sea-urchin, as the central type, from this globular animal we can trace through easy stages the development on the one hand of such radially symmetrical creatures as the Asteroidea, and on the other hand, from the same starting-point, we are led to elongated, linearly symmetrical, worm-like creatures, such as the Holothuroidea ; so that we are conducted downwards to the Cœlenterates by the one road, and upwards to the Annulosa by the other.

They comprise four well-marked orders :—

1. Echinoidea, Sea-urchins.
2. Asteroidea, Star-fish.
3. Crinoidea.
4. Holothuroidea.

Order 1. **Echinoidea.** An Echinus may be taken as a good central type of the entire class, and may be defined as

Fig. 15.



METAMORPHOSIS OF ECHINUS.

Pluteus paradoxus. 1. Apex of the body. 2. Lateral processes. 3, 3, and 4, 4. Four arms of the Pluteus body. 5, 5. Anterior and posterior processes of the framework of the mouth. *a.* Mouth in the midst of the four-pronged proboscis. *b.* Curved border of framework. *c.* Stomach. *d.* Constriction of gullet. *e.* Calcareous framework of the skeleton. 2. Central disc showing the further development of the Echinus, with commencing spines. *c.* and *d.* Disappearing calcareous framework. 3. More advanced state, showing the cirri and spines projecting from the surface, and the larval form almost gone.

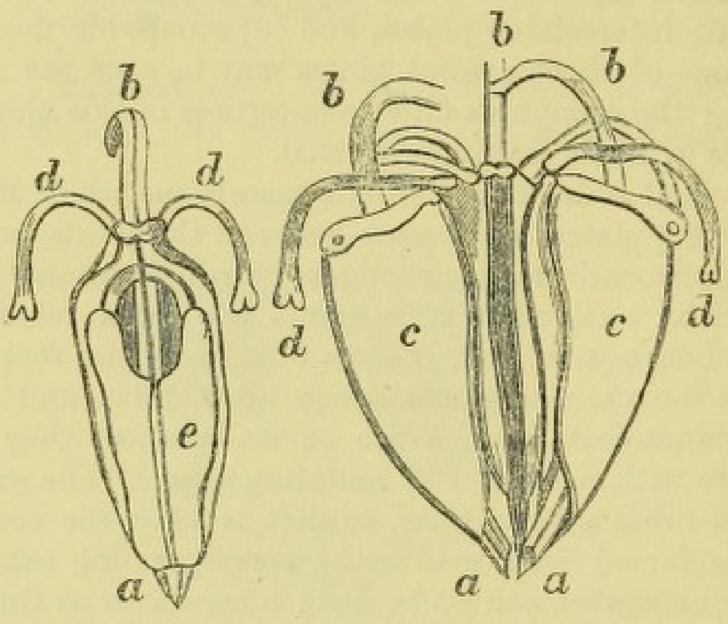
follows : a radially symmetrical animal, of a globular, or depressed form, encased in a calcareous shell or test, composed of many-jointed, immovable plates. The intestine is convoluted, suspended in a perivisceral space, and is supplied with both mouth and anus ; the former placed *below*, and the latter *above*. The larva is a Pluteus. The shell or test of an Echinus is formed of twenty rows of immovable plates, arranged in regular order from the apical to the oral pole, in ten alternating zones. Each zone is composed of five large imperforate plates, provided with a great number of short-jointed spines, which are auxiliaries in locomotion, and of five smaller perforated plates, called ambulacral plates ; the apertures transmitting the feet, or ambulacra. The apical end, in addition to five small circularly disposed plates, is surrounded by five large *genital* plates, each of which contains (1) a duct for the passage of ova or spermatozoa, (2) an ocellus or eye-spot placed on each of the five small intercalated plates, and (3) occupying the entire surface of one of these genital plates may be seen the madreporic tubercle : the numerous minute apertures in this elevation communicate with the madreporic canal.

The shell is developed from a membrane which lines the interior of the plates, and passes between the joints, so that additions can be made to their edges, by which means the animal increases in size, while it preserves the same relative proportions. Locomotion is effected as follows :—The feet which pass through the ambulacral canals are all hollow, and behind the shell communicate with a sac or water-butt ; they also communicate with each other by radiating tubes. The walls of these sacs and tubes are muscular, so that as each sac contracts, the water is forced from it into the corresponding tube, which is thereby elongated and protruded ; a sphincter at the end of the tube enables the animal to draw or roll itself along just the length of the contraction of the foot, and by this contraction the foot is retracted, and the water squeezed back into the water sac. The *Madreporiform vesicle* is also guarded by a muscle, and permits the ingress of water, excluding sandy particles, &c. to the general water-vascular system.

The mouth of an Echinoderm is one of the most complex in the entire Animal Kingdom, though evolution fails to show by what steps it has become so largely developed. It appears indeed to be not only one of the most perfect, but one of the earliest instances (the Rotifera alone preceding them) of a dentary apparatus in the Animal Kingdom. It is composed of fine, accurately-fitting vertical pyramids, an inch deep in the larger specimens, each provided with a rod-like calcareous tooth, worked by a couple of beautifully trochleated muscles. The intestine is tortuous, and is connected to the shell by delicate membranous mesenteries. The mouth and anus, though broadly speaking discal and apical, are really often eccentric in position. The Echinodermata are diœcious. *Echinidea* possess a true hæmal system; the heart giving rise to an aorta, which surrounds the gullet and intestine. The blood is aërated (by a process akin to branchial respiration), through exposure to the oxygen mixed with the water which is constantly circulating over the vascular mesenteries.

Echinodermata possess in addition to the structures already described, three other peculiar organs—*spines*, *pedicellariæ*, and *Pollian vesicles.*

Fig. 16.



DENTARY APPARATUS OF ECHINUS, OR ARISTOTLE'S LANTERN.

The right-hand diagram shows three of the teeth in position. *a a.* Cutting edges of the teeth, which are extremely hard. *b.* Fibrous roots of the teeth. *c c* Opposed bony surfaces of the jaws. *d d.* Arched processes. The left-hand diagram shows an isolated pyramid. *e.* External surface. Other letters as before.

Spines are numerous irregularly disposed processes, which are scattered over the test, and act as passive weapons of defence.

Pedicellariæ are minute almost microscopic, jointed spines, scattered all over the test of the Echinus, and terminated by a tripodal claw, capable of being closed like a pair of forceps upon any animalculi or offensive matters that may tend to obstruct its shell. The pedicellariæ act indeed in a twofold manner: by simultaneous movement (for they are worked by muscles) they waft nourishment to the mouth, and by their clasping power and jointed bases they can sweep a small area of the shell, and keep it free from molesting animalcules. These curious organs are merely modified spines.

Pollian vesicles are a cluster of free-hanging sacs, connected with the madreporic tubercle, and also with the ambulacral canals. They are muscular organs, and assist in the propulsion of the fluid contained in the canals.

The order Echinoidea contains the following families:—

Sub-orders. 1. *Spatiformes*, or Spatangoid sea-urchins. Flat or obovate in shape, with eccentric oral and anal apertures. No anterior ambulacrum.

a. Ananchytida. Ambulacra, simple.

b. Spantangida. Ambulacra, petaloid.

2. *Lampadiformes.* Oral aperture, central. Ambulacra, all similar. Anus often found in genital disc.

a. Echinoneida. Toothless, ambulacra simple.

b. Cassidulida. Toothless, ambulacra petaloid.

c. Clypeastrida. Toothed, ambulacra petaloid.

d. Echinoconida. Toothed, ambulacra simple.

3. *Globiformes.* Oral and anal apertures central; latter surrounded by genital plates.

a. Cidarida. No buccal branchiæ on ambulacra, which are prolonged over buccal membranes; spines unusually long and bright-coloured.

b. Echinidæ. Buccal branchiæ present, but ambulacra not prolonged over buccal membrane.

4. *Tesselata.* Corona of test consisting of more than twenty plates; all extinct Palæozoic Echinoderms.

Order 2. **Asteroidea,** Star Fishes. Radially symmetrical animals, composed of a small central body and five long radiating arms, with ambulacra below, and a coriaceous covering above, consisting of a muscular integument with thickly scattered calcareous particles. The central body presents two poles, a lower oral pole, and an upper anal orifice. The arms are hollow for a certain distance, to permit of cæcal extension into them of the stomach. The larva is bilaterally symmetrical, like that of Echinoidea, but is never enclosed in a skeletal framework. The upper, anal surface presents the madreporiform tubercle; neither the anus nor madreporic vesicle are central, and both are placed in what corresponds to the interambulacral area of a sea-urchin. There are no teeth. The hæmal system is arranged as in sea-urchins, a blood-vessel surrounding the gullet and intestine, the whole being placed internal to the ambulacral system. Purification of the blood is ensured by continuous currents of water being kept up by ciliary action; the water being admitted and then expelled through numerous contracted ciliary tubes, which form part of the ambulacral system, and are consequently situated on the lower aspect of the animal. Nervous system as in Echinoidea. Ocelli generally present. They are mostly diœcious, the young passing through an alternation of generations. In the first stage the embryo is ciliated; in the second stage an indentation takes place, making the body crescentic, the concavity is alone ciliated, and becomes the mouth, the convexity becomes the anus, an alimentary canal connecting the two; in this state the animal is bilaterally symmetrical, and is called a *Bipinnaria*. In the third stage, the future star-fish begins to be laid down in this larva, the ambulacral system and madrepore tubercle are first formed, then the arms radiate, and in the midst of the decaying *Bipinnaria* the *Asteridea* appears, the larva finally perishing, and the star-fish escaping free. They contain the following families:—

Section 1. Ambulacra, with four rows of feet.

Family. *Asteriadæ.* Madreporic tubercles present, and simple.

Section 2. Ambulacra, with two rows of feet.

a. Astropectinidæ. Back flattish, covered with tubercles, with radiating spines at the top called 'paxillæ.'

b. Pentacerotidæ. Body surrounded by longish or elongated pieces, covered with a smooth or granular skin, pierced with numerous holes.

c. Asterinidæ. Body discoidal, or pyramidal, sharp-edged; skeleton of flattish imbricated plates, madreporic tubercles, occasionally double.

Order 3. **Ophiuroidea**, Brittle Stars. Resemble the Asteroida at first glance, but are sharply marked off from them by the fact that the long slender arms are never pierced on their lower surface for the passage of the feet, nor do the arms contain prolongations of the viscera, as in the former order. No anus is ever present, the central inferior mouth serving the double purpose of oral and anal operation. The long arms are furnished with four rows of jointed ossicles, one row above, one beneath, and one on either side; they subserve purposes of locomotion, and also act as prehensile organs. The madreporic tubercle is placed near the mouth. The larva is a 'pluteus,' and is surrounded by a skeletal framework.

Families. *a. Ophiuridea.* Genital fissures, two; arms, five, simple.

b. Asterophydiæ. Genital fissures, ten; arms five; simple or branched.

Order 4. **Crinoidea.** Echinodermata, chiefly fossil, fixed to bottom of sea by a jointed stalk. The long, wavy arms, five or ten in number, are not locomotive, but respiratory organs. The mouth is superior ; anus, when present, inferior ; diœcious. The embryo free and ciliated. Type-forms, *Pentacrinus*, *Caput Medusæ*, and *Comatula* ; both recent and fossil. *Pentacrinus*, body formed of calcareous plates, prolonged into jointed stalk. Mouth and anus both present. It looks like a little, leafless, twiggy shrub, about $2\frac{1}{2}$ inches in height. Deep-sea dredgings have brought up many new Crinoids, formerly believed to belong exclusively to the Mesozoic period.

Comatulæ, or Feather Stars, are graceful, free-swimming Crinoids, only attached by a stalk when young. The central body is provided with ten wavy and freely-fringed arms, which serve as locomotive organs. Mouth central, and arms lateral. Larva bilaterally symmetrical ; imago radially so.

Order 5. **Cystoidea.** This order is entirely extinct, and is confined to the Palæozoic period (except, perhaps, a curious Australian Echinoidean, called Hypomone). The Cystoidea are fixed to the bottom of the sea by a short-jointed stalk; the body is sub-globular, enclosed in a dense, jointed coat of mail. The upper surface is generally devoid of arms; three openings are present, one oral, one anal, and the third the ambulacral orifice.

Order 6. **Blastoidea.** Entirely extinct. Palæozoic Pentacrinites somewhat like Cystoidea. Fixed by jointed stalks to the bottom of the sea. No arms; body of calcareous plates. Oral aperture central and superior, surrounded by five ovarian apertures.

Order 7. **Holothuroidea.** Sea-cucumbers, or Trepangs. Echinodermata of a slug-like form, from one to three inches in length, covered with a thick, soft integument, containing calcareous particles. From the oral aperture branched and feathery tentacles, processes of the water-vascular system, protrude into the water, while another internal development of the same system forms the beautiful 'respiratory tree.' Larva vermiform and without skeletal framework. Locomotion either by ambulacral feet, or, when these are not present, by jointed, anchor-like spines, or by muscular contraction of the body itself. The madreporiform tubercle does not open exteriorly, but ends in the perivisceral cavity. The intestine ends in a cloaca, whence two tubes proceed, one to the anus; the other passes up again in the substance of the animal, and after branching in a very free manner ends cæcally near the mouth, and forms the respiratory tree. The walls of the tubes are muscular. The whole integument is so muscular that a sea-cucumber can at a pinch eject its own viscera.

Family I. *Holothuridæ.*—Body coriaceous, with calcareous particles. Ambulacra and respiratory tube present.

Family II. *Synaptidæ.*—Body coriaceous, covered with spines, by which the animal moves. Ambulacra rudimentary or absent. Respiratory tube often (not always) absent.

Physiological Process of Annuloida.

In brief summary, the physiological process of Annuloida are as follows :—

Digestion.—All the Scolecida, except the Tæniada and Acanthocephala, possess an alimentary canal, which, in the Trematoda, the Gordiacea, and Turbellaria has only one inlet and no outlet; in the Rotifera, the Nematoidea, and some Turbellaria, there is both an oral and an anal aperature, and very often a pharyngeal dilatation or crop. All the Echinodermata have a well-developed intestinal canal, distinct from the walls of the body, and provided with both oral and anal apertures, which are situated directly opposite each other.

Circulation and Respiration.—The only organs present for the performance of these functions are the water-vascular system of the Scolecidæ, and the ambulacral vessels of the Echinodermata. They subserve the double purpose of circulatory and respiratory organs. Most of the ambulacral vessels are lined with cilia.

Nervous System.—Only possessed of a sensori-motor and excito-motor power. No real volition yet present. In other words, all the movements are of a reflex character; there is a low degree of sensation in some.

CHAPTER X.

Sub-Kingdom : Annulosa—Sub-Division : Annelida.

Annulosa.—Synonyms, *Homogangliata* (Owen) : *Articulata* (Cuvier.)

Definition.—The body of the *Annulosa* is divided into segments, called somites, which are arranged in a longitudinal manner. The covering of these somites is dense, and gives insertion to powerful muscles. The nervous system is very well developed, and always arranged in a definite way, and a way which is peculiar to this sub-kingdom. The gullet is surrounded by a nervous collar, with one large ganglion (*supra-œsophageal*) above the gullet, and from this collar a double gangliated cord is extended. Two ganglia for each segment succeed, which pass down the whole *ventral* aspect of the animal. Limbs, when present, are neural.

ANNULOSA are primarily divided into two great groups, according as the creature has jointed limbs or not, called respectively Arthropoda and Annelida : the distinctive characters of each of these we must define.

Arthropoda (*ἄρθρον*, a joint ; *ποῦς*, a foot) always possesses articulated limbs, appended to a dense exo-skeleton. There is perfect bilateral symmetry in all the parts of the body, both external and internal. The organs of vision are highly developed. The jaws move transversely, and the head is supplied with feelers and antennæ. Neither the embryotic nor adult arthropod ever possesses cilia. In the place of a heart they possess a distinct dorsal vessel, which is valved, and contracts rhythmically.

Annelida are worm-like animals, with a soft integument, which is, with the exception of the Gephyrea, always segmented; they do not possess jointed limbs. The organs of sense are very simple. There is no distinct valved contractile dorsal vessel ; but nearly all possess vessels which, by a sort of physiological compromise, are called *pseudo-hæmal ;* they contain a corpusculated, and often greenish fluid, and the vessels entering into their composition, are often much convoluted, and provided with thin sacs or hearts. The head is little differentiated from the rest of the body segments; the separate segments are often very numerous, sometimes numbering four hundred. In the highest members of the group each segment bears two sets of lateral appendages, or *oars*—two dorsal and two ventral; besides these, other appendages, termed *cirri*, are carried dorsally, and near to them again are the branchiæ. The foot tubercle is provided with setæ, which are locomotive organs. The intestine

Fig. 17.

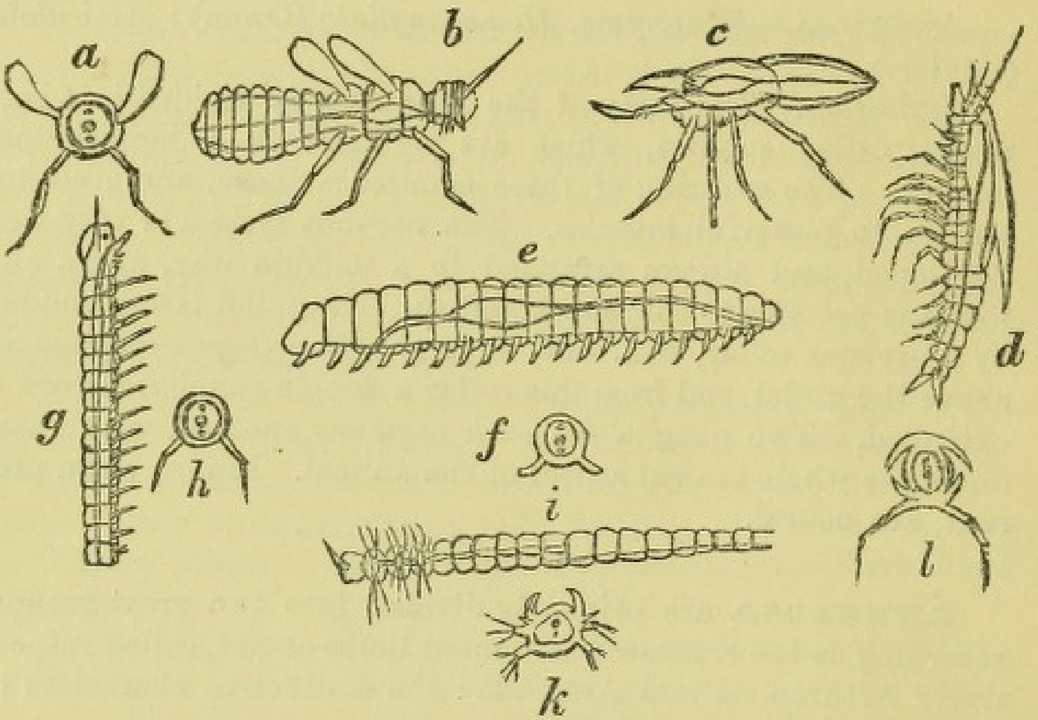


Diagram to show the general Morphology of Annulosa.

e. Common plan, showing the dorsal hæmal system above, the neural system below, and the digestive system between the two. *f.* The same in section, showing the same relative position of the blood, nervous and digestive systems. *a* and *b.* Diagram in section and profile of an insect. c. A spider. *d* and *l.* Crustacean at length and in section. *g* and *h.* A myriapod at length and in section. *i* and *k.* An annelid in full length and in transverse section.

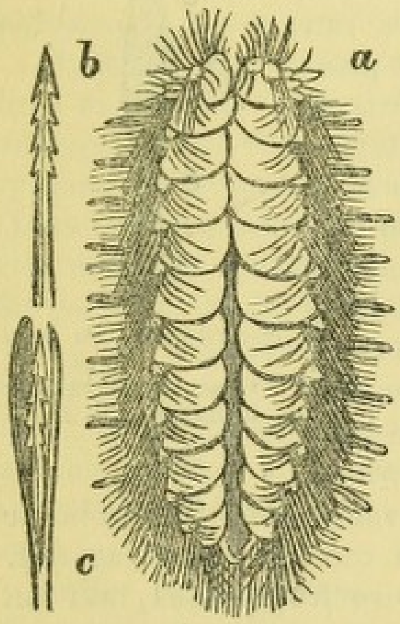
is always proctous, nearly always straight, and is suspended in a perivisceral cavity.

The Annelida, which is only of the value of a class, contains five orders—Errantia, Tubicola, Terricola, Suctoria, and Gephyrea.

Order 1, **Errantia** (Nereidea), includes Sea Mice, Sea Worms, and Sand Worms. Branchiated Annelides, the branchiæ being either dorsal or lateral. The pseudo-hæmal vessels contain a red or green corpusculated fluid. Integuments soft. Each segment presents a ventral and a dorsal arc, with 'foot tubercles' on either side. The dorsal oar is called a 'notopodium;' the ventral oar a 'neuropodium.' Each carries setæ, and a soft vascular structure termed the 'cirrhus.' The mouth is furnished with jaws which, like the jaws of insects, work laterally. 'Segmental' organs are present. These are small cæcal diverticula placed laterally. They open externally, secrete mucus, and act as excretory organs. They are unisexual, and the animals go through a metamorphosis during development.

Type-form, *Aphrodite*, or *Sea Mouse*. This brilliantly tinted worm has its back covered with large imbricated plates, forming the 'elytron.' The interspaces between the plates admit the water to the branchiæ, which are lodged in the space below. Feelers of large size are present, and the head is supplied with eyes of some complexity. Setæ and sharp spikes, armed with recurved barbs, are appended to the oars, and moved by muscles. Reproduction by gemmation, and by congress of sperm and germ cells; the two processes occurring alternately; thus the ova sexually produced grow into Annelides, which multiply gemmiparously, and these in turn produce the oviparous Aphrodites.

Fig. 18.



ANNELIDA.

a. Aphrodite aculeata (Dorsal aspect). *b.* Barbed setæ. *c.* The same enclosed in their smooth horny sheath.

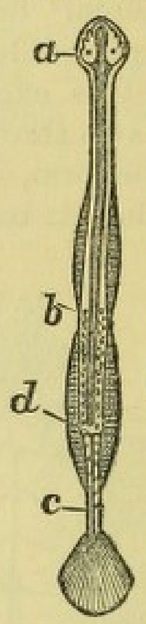
Another well-known member of the order Errantia is the *Arenicola piscatorum*, or Lob-worm, which dwells in the sand on the sea-shore. This worm has thirteen pairs of branchiæ on each side of the body; it has also a short proboscis, but is destitute of eyes and jaw.

Some of the Nereidea, *e.g. Eunice gigantea*, attain a considerable size, the last-named animal measuring about four feet, and having a body composed of 400 segments.

The species *Sagitta* (fig. 19) may here be referred to, but it is so very aberrant a form, that it is sometimes raised to the dignity of a separate class, which is styled Chætognatha (χαίτη, a mane; γνάθος, a jaw). Sagitta is a marine, transparent Annelid, about an inch long. Its head is round, and furnished with six sets of setæ, two large—like feelers—near the mouth, and four short, at the side of the mouth. The posterior part of the body, which tapers to a point, is fringed with a delicate membrane. They are monœcious, and do not pass through any metamorphosis in reaching maturity.

Order 2, **Tubicola,** are branchiated Annelides, which have received their name from dwelling in tubes, some, as in Serpula, formed of calcareous particles, which are secreted by the integumental covering, whilst others, like Terebella, construct their habitation of grains of sand, pieces of broken shells, and other heterogeneous substances, which they glue together by aid of a colloid secretion. The Tubicola somewhat resemble miniature French horns in appearance, and the animals can leave the tubes in which they dwell, at pleasure. The branchiæ are arranged in lateral plumes, and are always cephalic. Reproduction takes place sexually, and also fissiparously. The embryo is at first free and ciliated, afterwards it loses its cilia, and develops the tube by a process of epidermic secretion. Type-form, *Serpula*, a worm common on our coasts; the tube is narrow and spiral, measuring about one-sixth of an inch in diameter. One of the tentacles with which the head is furnished is specially developed to form a lid or operculum, whereby the open mouth can be closed at will. When this is done the animal is secure from attack, and can sleep in peace.

Fig. 19.



Sagitta bipunctata from below. *a*. Head. *b*. Ovary. *c*. Testicular chamber. *d*. Anus.

Order 3, **Terricola,** are perhaps more correctly called Oligochæta (ὀλίγος, few; χαίτη, hair), as they include both land and water worms. They possess no external branchiæ, but respire by means of numerous internal ciliated processes. They move by means of very short ventral setæ. The nervous system is often ill developed. In the earthworm it is a simple cord, with scarcely any trace of ganglia. They are monœcious. They are divided into two groups, the *Terricola proper* and the *Naïdidæ*.

The common earthworm, or *Lumbricus*, may be taken as the type-form of the *Terricola* proper. It is a round worm, composed of numerous segments. The anterior segments concerned in reproduction are called the 'clitellum' or 'saddle.' The mouth is edentulous, and the gullet straight; the latter leads into a small muscular dilatation, the 'proventriculus,' which conducts to the 'gizzard,' or stomach; this, in its turn, leads to a short, straight, anally ended intestine. The entire arrangement of the alimentary canal is interesting in itself, and in its nomenclature, as foreshadowing the plan that is met with among the class of Birds. Segmental organs always present, and the pseudo-hæmal system very like the water-vascular system of Tæniadæ.

Naïdidæ are bright red little fresh-water worms, about an inch long, and corresponding in anatomy to the earthworm. Reproduction as follows : an adult Naïs develops a bud between two of its body segments ; the bud itself, and the two portions of the body, the one in front and the other behind the bud, all grow, without sexual congress, into adult and perfect Naïdidæ. These fissiparously produced individuals develop ova and spermatozoa, and give birth to future Naïds by sexual congress.

Order 4, **Suctoria,** comprise the Leeches, and may be defined as aquatic worms, with a soft segmented body provided with a suctorial disc at one or both ends. The body is moved by powerful muscles. The alimentary canal is short and simple. There are seventeen 'segmental organs' on either side of the body. The mouth is sometimes edentulous, but sometimes, as *e.g.* in the common leech, *Hirudo medicinalis*, is armed with powerful teeth. In the animal named, the mouth has thin lips, each of which is furnished with a semi-lunar finely serrated blade, or tooth, which being lodged in the powerful subdermic muscles, can be worked in a sawing fashion with great effect. The horse-leech (*Hæmopsis*), so common in all our streams, has no teeth.

Order 5, **Gephyrea,** contains the genus *Sipunculus*. The Sipunculi are marine, or rather coast worms, from half-an-inch to two feet in length, with bodies sometimes plainly, but often only faintly segmented. At the anterior end we find a tentaculated mouth, and a retractile proboscis ; an anus is present on the dorsal surface, but usually in anterior third of the animal's length. They are diœcious ; the alimentary canal is convoluted, and closely resembles the ambulacral system of Echinodermata, though without ambulacra. The entire order, indeed, corresponds about as closely to the Echinodermata as to the Annelida, and is clearly the connecting link between the two classes.

CHAPTER XI.

SUB-KINGDOM: ANNULOSA—CLASS: CRUSTACEA.

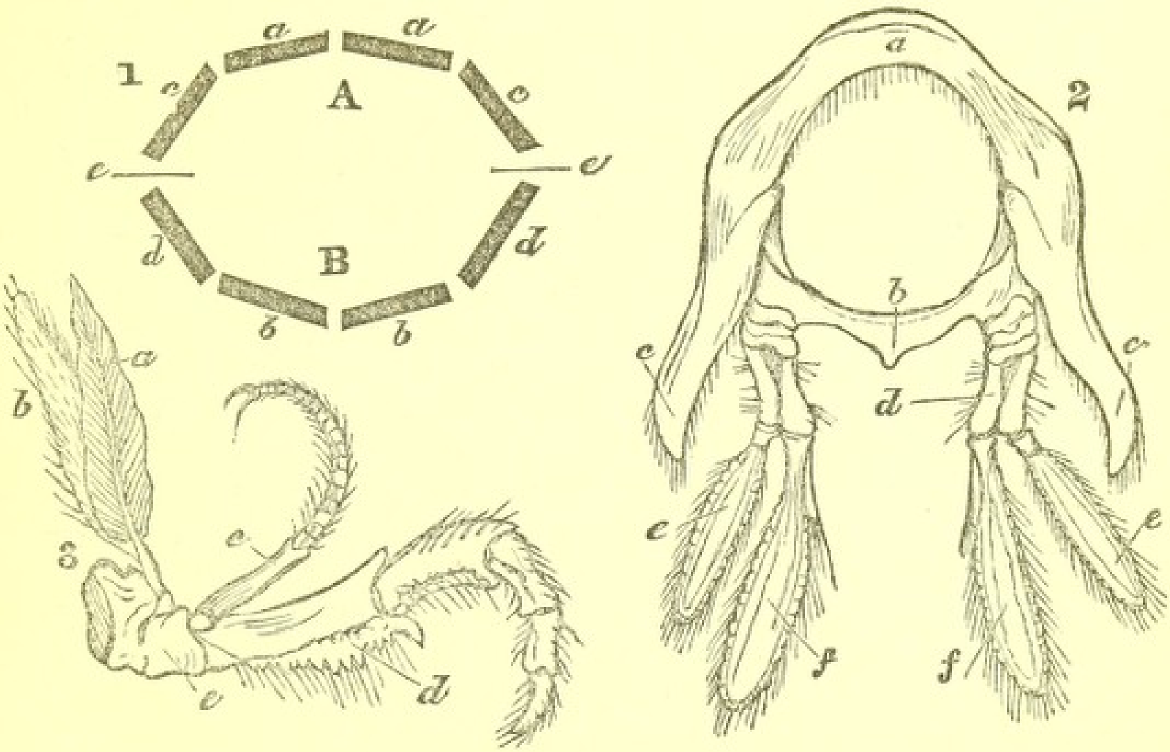
ANNULOSA.—The remaining classes of Annulosa are grouped together as Arthropoda, and are distinguished from Annelida by the possession of jointed appendages. Their definition has been given at the commencement of the preceding chapter. They contain the four great classes of Myriapoda, Arachnida, Crustacea, and Insecta.

Although Crustacea constitute a high class of Annulosa, it is taken first, as it affords a good central type, around which the other sections may be grouped.

CRUSTACEA. Lobsters, Crabs, Barnacles, &c.

Definition.—Annulosa with jointed limbs; breathing by gills, or by the surface of the body. Two pairs of antennæ are present. The locomotive appendages are borne by the abdominal as well as the thoracic segments, and are more than eight in number. Two or more of the appendages are modified to form a manducatory apparatus. The appendages modified into limbs vary from five to seven pairs in number. A typical Crustacean consists of twenty somites, six of which, often welded together, are cephalic, eight thoracic, and six abdominal. The cephalic and thoracic segments, being more or less amalgamated, form the cephalo-thorax. Each somite has a pair of appendages, some of which, termed 'antennæ,' are devoted to the most various uses, *e.g.*, they may be organs of touch, and of smell, as in Decapoda, or they may be digging organs, as in Scyllarida, or of prehension, as in Merostomata, or claspers for the male, as in Cyclops, or serve as organs of attachment, as in Cirripedia. Each somite is composed of several bilaterally symmetrical parts, forming a dorsal or *tergal arc*, and a ventral, or *sternal arc*; each half of the tergal arc is formed of a superior piece, the *tergum*, and a lateral piece, the *epimeron*, to which the pleuræ are joined; each half of the *sternal arc* is formed of an inferior piece, the *sternum*, and a lateral piece, the *episternum*. Septa, called *apodemata*, pass inwards from the junction of these various pieces. The entire body is encased in a strong chitinous exoskeleton, which in many, *e.g.* in the Lobster, is further strengthened by a powerful dorsal shield, the *carapace*, formed by the enormous development of the tergal and epimeral pieces of the first fourteen somites. The last abdominal somite is terminated by an azygos segment, the *telson*, which, being single, is regarded by some as an appendage, and by others as a true somite, because it is pierced by the termination of the intestine. Taking the Lobster as our type-form, we find the

Fig. 20.



MORPHOLOGY OF THE LOBSTER.

1. Diagram of exoskeleton. *A*. The tergal, and *B*. the sternal arcs. *a a*. the tergal pieces. *c c*. Epimera. *b b*. The sternal pieces. *d d*. Episternum. *e e*. Insertion of extremities and pleuræ. 2. One of the somites separated. *a*. Tergum. *b*. Sternum. *c*. Pleuron. *d*. Protopodite. *e*. Exopodite. *f*. Endopodite. 3. A foot jaw or maxillipede. *a*. Gill. *b*. Epipodite. *c*. Exopodite. *d*. Endopodite. *e*. Protopodite.

somites possessing the following appendages: Each abdominal segment, regarding the telson as an appendage, is supplied with a pair of jointed limbs, called *swimmerets*. Those attached to the first somite, that is, the one succeeding the thoracic somites, are the largest, and act as paddles. Each is formed of a short piece, jointed to the sternum, called the *protopodite*, or *basipodite*, and two larger, fringed and somewhat flattened segments, the outer of which is called the *exopodite*, and the inner the *endopodite*. The remaining abdominal somites possess similar appendages until we reach the first piece, when we find that the swimming legs are modified into walking legs by the suppression of the exopodite. The last thoracic segment carries a similar pair of ambulatory legs, except that the protopodite bears a little process, the *epipodite*, which serves to support and keep the branchiæ open. The last somite but one has similar appendages, but their extremities are converted into small nippers, called *chelæ* ; the next segment carries similar kinds, and so does the succeeding one, but the chelæ are developed out of all proportion to the preceding, and form the great claws. The two next segments carry appendages modified to form manducatory organs, and called *maxillipedes*, or *foot jaws* ; they are composed of the same elements as the swimmerets and walking legs. The next two segments, which are cephalic, carry appendages in the form of jaws, and called the *first and second pair of maxillæ*. Still the same elements are recognisable, but the epipodite of the first pair is rudimentary, and that of the second pair is large, shaped like a spoon, and called the *scaphognathite* (σκάφος, a boat ; γνάθος, a jaw), and serves to keep up a constant current of water through the gills by continuously baling out the water which they contain. The next segment bears the biting jaws or mandibles ; in them the endopodite is very small, and is called the *palp* ; the protopodite is large, and forms the greater portion of the jaws ; the exopodite is undeveloped. The mouth is placed between, and at the base of the mandibles ; the upper lip is formed by a single plate, and is called the *labrum* ; the lower, or hinder lip, is a forked process, and is called the *metastoma* or *labium*. The succeeding cephalic segment carries the long antennæ, or feelers, in which we still recognise the protopodite, a long-jointed endopodite, and a small exopodite. The next somite supports the smaller antennæ, and the next, which is the most anterior of all, bears the *eye-stalks*, at the end of which the eyes are placed, and which eye-stalks are simply protopodites.

Such is the typical arrangement of the somites in the Crustacea, but in some cases the segments mentioned above are not all developed, an arrest of development having taken place. Both the limbs and gills are always placed on the ventral surface.

The *alimentary canal* of Crustacea is simple, terminating at the telson by an anus, and has a well-developed liver in connection with it. Salivary glands sometimes, but not always, present. The blood, which contains oat-shaped cells, is for the most part contained in vessels, and propelled by a distinct heart; the course of the *circulation* is as follows: The heart is placed in the dorsal region, and consists of a strong muscular ventricle, and an auricular venous expansion above; in other words, it is bilocular. From the ventricle the blood is pumped along several arteries into numerous lacunæ, which occupy the interstices of the body, and through which the blood passes into veins furnished with muscular dilatations, as it were venous ventricles, and by them is conveyed for purification to the gills, whence the branchial veins, carrying arterial blood, convey it to the venous sinus, which partially surrounds the heart, and so completes the circuit of the blood current. From this it will be seen that the heart of Crustacea is systemic, *i.e.* it pumps the blood directly to the viscera and the body generally; this we shall see is the case in the hearts of all Invertebrates possessing these organs; whereas in Vertebrates the heart is as invariably respiratory in the first instance, *i.e.* it forces the blood to the gills or lungs for purification, and only secondarily propels it to the entire system.

The *nervous system* is arranged on the same general plan as in the rest of the Annulosa. The supra-œsophageal, or cephalic ganglion, supplies the organs of sense. The ventral cord is supplied with six thoracic and six abdominal ganglia, which supply the muscles and viscera; the viscera, however, have other special ganglia.

Senses.—The eyes are often large, stalked, and compound—*the structure of the compound eye is described under the class Insecta.* An auditory apparatus, consisting of a sac filled with water, containing otoliths, and communicating by nerves, first with the sub-œsophageal and then with the cephalic ganglion, is placed at the base of the lesser antennæ. In *Mysis* the auditory sacs occupy the anomalous position of the last abdominal exopodite, and a gland, something like the cement gland of Cirrhopoda, is placed near the sac. The sense of smell is by some believed to be combined with that of hearing, or rather that the organ just described is an organ of smell and not of hearing. It is possible that the single nerve may have the double sense.

In *Reproduction*, the Crustacea are diœcious, and particulars will be given under the heading of the different orders, of the mode in which each order produces its like; the organs of reproduction are, however, as follows: *Female organs* consist of *two ovaries*, provided with ducts, which open through the base of the third ambulatory leg. *Male organs* consist of *two testes*, situated in the thorax, each yielding its secretion to a *vas* *deferens*, which leads to a musculo-membranous *penis*, which can be protruded through an opening in the basal joints of the last thoracic limb. The first and second abdominal limbs possess appendages which are partly used to excite the female, and partly to guide the male organ.

Crustacea contain the following orders :—

Order 1. Podophthalmia, or Decapoda.—Crabs, Lobsters, Shrimps, &c.
,, 2. Edriophthalmia, comprising Isopoda, or Wood Lice ; Amphipoda, or Sand Hoppers ; and Lœmodipoda, or Whale Lice.
,, 3. Stomapoda comprise Mysis and Squilla.
,, 4. Branchiopoda include Daphnia, &c.
,, 5. Ostracoda include Cypris and Cythere.
,, 6. Cirripedia comprise Acorn Shells, and Barnacles.
,, 7. Copepoda comprise Cyclops and certain parasites formerly called Epizoa.
,, 8. Merostomata contain the King Crabs, and many extinct forms.
,, 9. Trilobita are extinct Palæozoic Crustacea.

1 and 3 form Thoracostraca

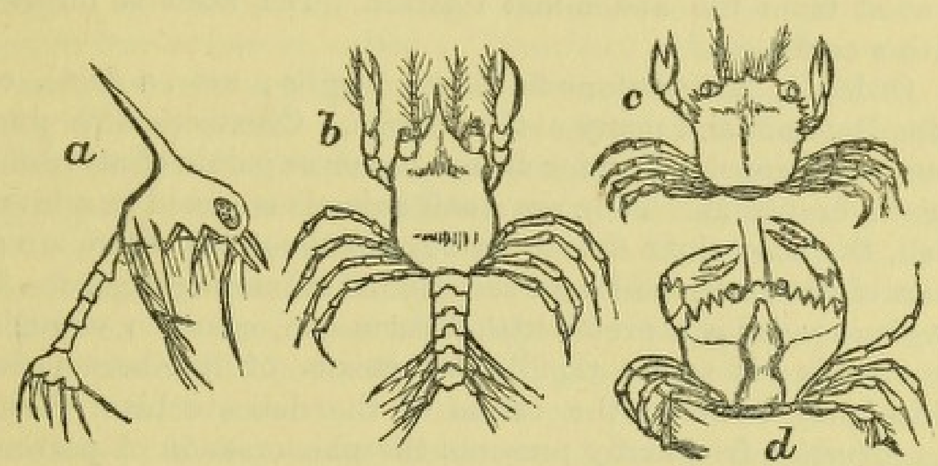
Order 1. **Podophthalmia** (ποῦς, a foot ; ὀφθαλμός, an eye), or **Decapoda**, are the most highly organised of all the Crustacea. They possess compound eyes, placed on stalks, which spring from the first cephalic segments. The body contains twenty somites, and a carapace is always present, formed by certain portions of the thoracic segments. There are five pairs of walking legs, of which the anterior are *chelate*.

The principal points in the morphology of the Decapoda have been given above in the sketch of the type-form, the Lobster, which was taken to describe the class.

The *Anomura*, or *Hermit Crabs*, differ from *Macrura* (the type), in having a soft integument, and being dependent on the forsaken homes of others for safety. The abdomen, too, does not terminate in a caudal fin, and the tail is very small, though not entirely absent. They possess a sucker, by means of which they adhere to the shell they enter. One of the larger 'chelæ' is developed more than its fellow, thereby serving to close the aperture of the shell when the animal has retired to rest.

The *Brachyura*, or *Crabs*, again differ from the Lobster, in having the abdominal and caudal segments, which serve as shelves for carrying the ova, tucked underneath the cephalothorax. The limbs, too, are all modified for walking. There is one large central ganglion, whence nerves radiate to all parts of the body. This is about the most perfect instance of concentration of the nervous system met with in any Invertebrate below the Cephalopoda. It is in their *reproduction*, however, that the Decapoda are most remarkable, all passing through a very curious metamorphosis. The impregnated ovum being extruded from the oviduct, grows into a little creature called a 'zoea,' not in the least resembling the parent form. It is a comical-looking animal, with a large head, capped by a sort of helmet, with a long point in front, and a large spike projecting from its posterior aspect; there are also two large eyes, and a well-developed abdomen, terminating in a bifid telson. In this

Fig. 21.



METAMORPHOSIS OF CRUSTACEA.

Carcinus mœnas. *a.* Larval or first form. *b.* Second stage. *c.* Third stage. *d.* Final stage, in which the metamorphosis is complete.

condition there are no gills, and no thoracic segments. It is only by a succession of 'moults' that the zoea attains the dignity of Lobster, or Crab-hood.

Order 2. **Edriophthalmia** (ἑδραῖος, sessile; ὀφθαλμός, eye). The eyes are both simple and compound, and, as the name indicates, are sessile, and never supported on eye-stalks. The body has no carapace. The mandibles possess palpi. The branchiæ are either thoracic or abdominal. Several, never less than five, of the posterior thoracic segments are freely movable. The *Isopoda*, comprising Wood Lice, &c., are distinguished by possessing seven thoracic segments for seven pairs of limbs, compound eyes, and a distinct shield on the head. The formidable little *Limnoria terebrans*, which by boring is so destructive to shipping, belongs to this group. Its boring apparatus is a modification of the maxillipedes. All the individuals of Isopoda pass through a metamorphosis; the young are free swimmers, the adults very sluggish. The *Amphipoda* or Sand-hoppers are small Crustacea characterised by possessing a well-developed abdomen, and vesicular respiratory organs which are attached to the bases of the legs. They do not pass through any metamorphosis. The *Lœmodipoda*, or Sea Lice, are minute aquatic crustacea possessing similar respiratory organs to the former group, but no abdominal somites. The first pair of legs is placed below the neck, and the head is furnished with four setiferous antennæ. No metamorphosis.

Order 3, **Stomapoda** (στόμα, a mouth; πούς, a foot), comprises Squillida, Glass Shrimps, Opossum Shrimps, and Locust Shrimps. They are marine Crustacea with pedunculated, compound eyes, a soft membranous shell, and branchiæ suspended from the abdominal somites. The head is furnished with a carapace.

Order 4, **Branchiopoda** (βράγχια gills; ποῦς, a foot), contains Daphnia and many extinct forms. Crustacea with numerous legs formed either for swimming or as points of attachment for the branchiæ. They are small animals enclosed in a bivalve shell, the head alone extending beyond the shell; there are two pairs of antennæ, the larger serving for swimming organs. The *Daphnia pulex* is a pretty little Crustacean, common enough in our ponds; it swims rapidly by means of its thoracic legs, which play between the valves of the delicate bivalve shell. *Reproduction* frequently presents the phenomenon of parthenogenesis. This is most noticeable in Chydorus sphæricus, where it has been observed through fifteen generations. The females are much more numerous and larger than the males, and contain two kinds of eggs, winter eggs and summer eggs; the summer eggs are numerous and ventral in position, the winter eggs are two in number and placed in a little dorsal receptacle, the *ephippium* or saddle. Both kinds of eggs, though at different seasons of the year, develop into perfect Daphniæ, which in their turn produce other Daphniæ, and then again others (gemmiparously), without any sexual congress.

Order 5, **Ostracoda**, Freshwater Shrimps (ὀστρακώδης, adj. from ὄστρακον, shell), includes Cypris. They are small Crustacea of a somewhat degraded type. They are enclosed in a hard bivalve hinged shell, the hinge being worked by an adductor muscle. The somites are very imperfect. The abdomen is rudimentary, and there is no distinct heart; the male reproductive organs are very large. No metamorphosis, but parthenogenesis sometimes takes place.

Order 6. **Cirripedia** (*cirrus*, a curl of hair; *pes*, a foot). Comprises Acorn Shells, Barnacles, &c., and is a curious order of Crustacea, embracing pedunculated, sessile, and apodal forms.

The embryos are free, but the adults are fixed (by a cement poured out by a gland connected with the ovary) to some foreign object. It is the cephalic portion alone which is thus fixed, the hinder part is free and can be protruded through the shell. The Cirripedes are supplied with six pairs of ciliated legs, which serve as prehensile organs. The antennæ, eyes, and abdomen are all rudimentary. The blood is white, and there is no distinct heart. The Acorn Shells, *Balanidæ*, are sessile ; the Barnacles, *Lepadidæ*, are stalked, and consist of a peduncle sometimes as much as two feet in length, and a capitulum, the peduncle containing the anterior part of the animal, the capitulum the rest. They are generally hermaphrodite, and pass through a metamorphosis during *reproduction*. The larva is a one-eyed free-swimmer, called a 'Nauplius,' which after one or two months becomes a pupa, enclosed in a bivalve shell by a folding of the dorsal portion. The anterior limbs, formerly paddles, become prehensile organs, the posterior continue swimming organs. At this period there is no mouth, but after the cement glues the animal to same rock the mouth is developed, the posterior limbs become prehensile, and the Barnacle is complete. In one genus of Cirripedes, *Scalpellum*, two very minute males are lodged within the shell of the hermaphrodite cirripede, which consist of little more than sacs filled with spermatozoa ; these curious bodies are termed 'Complemental males.'

Order 7, **Copepoda** (κώπη, an oar ; πούς), or Water Fleas, includes Cyclops and other aquatic forms. Some, like the Cyclops, are free and active ; others, the Epizoa, are sluggish and parasitic. The *Cyclops* is a small Crustacean with oar-like feet, enclosed in a thin bivalve shell. It has a single eye placed in front of the antennæ. The feet are five in number. Several moults occur during development. The *Epizoa* are free as embryos, but in adult life are parasitic upon the skin, or gills, or eyes of fishes. They are very small, and of most simple organisation. They do not possess gills, but breathe by the general surface of the body, like a protozoon. They possess a suctorial mouth, due to the elongation of the labrum and labium. They possess antennæ and eyes. The body is divided into cephalo-thorax and abdomen. The limbs or mouth are variously modified for attachment to their host. The males are always very much smaller than the females, and are sometimes attached for life to a female.

A very aberrant group, called *Rhyzocephala*, are astomatous, and in their pupa stage, when attached to crabs, &c., they become simple sacs filled with ova ; from the sac tubes proceed which penetrate the tissues of their victim and twine themselves like rootlets around its viscera. The embryo of these most extraordinary Crustaceans is a free-swimming larva with a single median eye.

Order 8. **Merostomata** (μηρός, thigh; στόμα mouth) include *Xiphosura*, the *Limulus*, or King Crab, and many extinct forms. They are the largest of all Crustacea, possessing mouths supplied with mandibles and maxillæ, whose extremities are modified to form walking or swimming feet. The anterior segments are amalgamated to form a strong buckler, with ocelli, and compound eyes, placed upon its dorsal surface. The hinder extremities are free, with broad lamellar, ventral appendages, terminated by the telson, which is prolonged into a long, strong, and sharp spear-like process.

The *Limuli* possess six chelate legs round the mouth, with spinous bases serving as manducatory organs. There are also six pairs of ventral appendages which carry the gills. The venter, like the dorsum, is protected by a buckler or operculum. The Palæozoic forms, *Pterygote* and *Eurypterida* belong to this order.

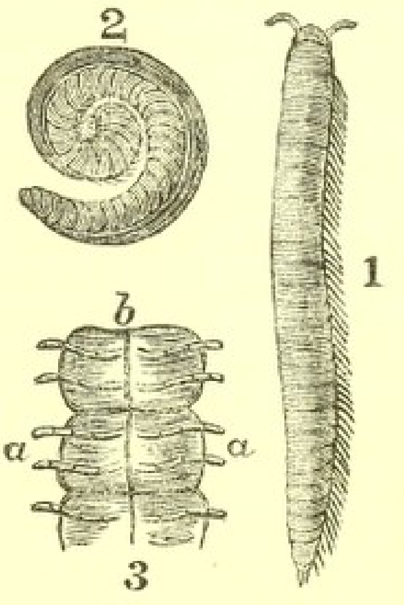
Order 9. **Trilobita** (τρεῖς, three; λόβος, lobe) are all extinct Crustacea, found only in the Palæozoic strata. The dorsum was protected by a three-lobed carapace, but the venter was unprotected. Eyes were sessile and borne by the carapace. The mouth was furnished with a large labrum; the telson was rudimentary. Many of these Crustaceans could roll themselves into balls like the common Oniscus. They swam on their backs, lived far from the shore, and in shallow water. They are common objects in every cabinet of Natural History.

CHAPTER XII.

SUB-KINGDOM : ANNULOSA—CLASS : MYRIAPODA.

MYRIAPODA include the Centipedes and Millipedes. They are characterised by the body being composed of more than twenty somites ; to each of which legs are appended. The segments increase in number with increasing age. This fact distinguishes them from Insecta. The head consists of six somites, more or less welded together. The covering is very firm and hard. The air is drawn in through little holes or *spiracles*, situated upon the surface, and conveyed to tubes, called *tracheæ*, by means of which it is distributed to the entire body. The eyes are numerous and sessile. In *reproduction* they do not pass through a true metamorphosis, but the embryo has frequently a less number of legs than the adult, only acquiring its full complement after several moults. They contain three orders, Chilopoda, Chilognatha, and Pauropoda.

Fig. 22.



MYRIAPODA.

Julus terrestris. 1. Full length view. 2. The same coiled up by muscular contraction of longitudinal bands. 3. Three segments, enlarged, to show the mode of attachment of feet (*a a*) to the (*b*) abdomen.

Order 1. **Chilopoda** (χεῖλος, a lip ; πούς, a foot) are the Centipedes. The body is flattened, with a generative pore at hinder end. Legs not extremely numerous, from fifteen to twenty pairs. Mouth possesses a hollow duct for the passage of fluid from poison gland. Palpi and maxillipedes both present. Two last somites form a tail ; the terminal somite is sometimes curved into a formidable hook (as in the Scorpion), which is hollow and conducts a poisonous fluid from a caudal poison gland. The Chilopoda are harmless animals in temperate climates, but often very dangerous in hot countries ; examples, *Scolopendra*, *Geophilus*, and *Lithobis*.

Order 2. **Chilognatha** (χεῖλος, lip ; γνάθος, jaw) are Millipedes and Gallyworms. Body round, with generative pore at the anterior extremity. Legs very numerous, often a hundred pairs, each somite, except the cephalic ones, possessing two. Mouth has no palpi. Lower lip composed of confluent maxillæ. Type-form, the *Miller*.

Order 3. **Pauropoda** (παῦρος, few ; πούς) contains a single genus, *Pauropus*, a minute Myriapod, $\frac{1}{20}$th of an inch long, possessing ten setiferous somites. Legs, nine pairs. Antennæ, bifid and five-jointed, with three long appendages. Respiration through skin. No foot jaws. White in colour. Found on decaying leaves.

CHAPTER XIII.

Sub-Kingdom: Annulosa—Class: Insecta.

Insecta.—The class of Insecta contains more species than all the rest of the Animal Kingdom put together, there being 150,000 already defined; but it is distinguished very readily from all the rest by perfectly definite characteristics.

The body is divided into three segments: a head, thorax, and abdomen.

The head contains the organs of sense, and supports two antennæ. The eyes are always compound.

The thorax consists of three somites, which always support three pairs of articulated legs, and sometimes give attachment to two or four wings.

The abdomen, composed of eleven somites, more or less welded together, contains the viscera and organs of reproduction. Legs are never attached to the abdomen.

The respiration of insects is effected by means of tracheæ, which ramify through every part of the body. Many insects pass through certain metamorphoses, as follows:—

The female insect lays eggs, which grow up into *caterpillars;* in this stage the insect is called a *larva.* This larva, after laying up good store of food, goes to sleep and becomes wrapped up in a mummy-like case, when it constitutes the *chrysalis*, *nympha*, or *pupa;* this is the second stage of insect metamorphosis. The third and last is reached by the insect bursting its swathing-bands and becoming a gay denizen of the air; this, the perfect insect, is termed the *imago.*

The compound eye of insects and the silk-spinning apparatus which some possess in their larval stage require brief description.

The *compound eye* is thus formed. Two optic nerves are given off from the supra-œsophageal ganglion, each of which spreads out into a secondary ganglion. From this a vast number of exceedingly short branches are given off, which pass through an expanded pigmentary tunic, called the *common chloroid*, and then dilate into a nervous layer, the *common retina.* From this retina a multitude of long filaments are given off, each of which terminates in a little corneal prism, the *corneal facets.* The common house-fly possesses about 8,000 of these, each of which, from being connected with a separate nerve, constitutes a separate and perfect organ of vision; other insects possess even a greater number.

Some insects spin silk. Spiders spin webs. The apparatus

Fig. 23.

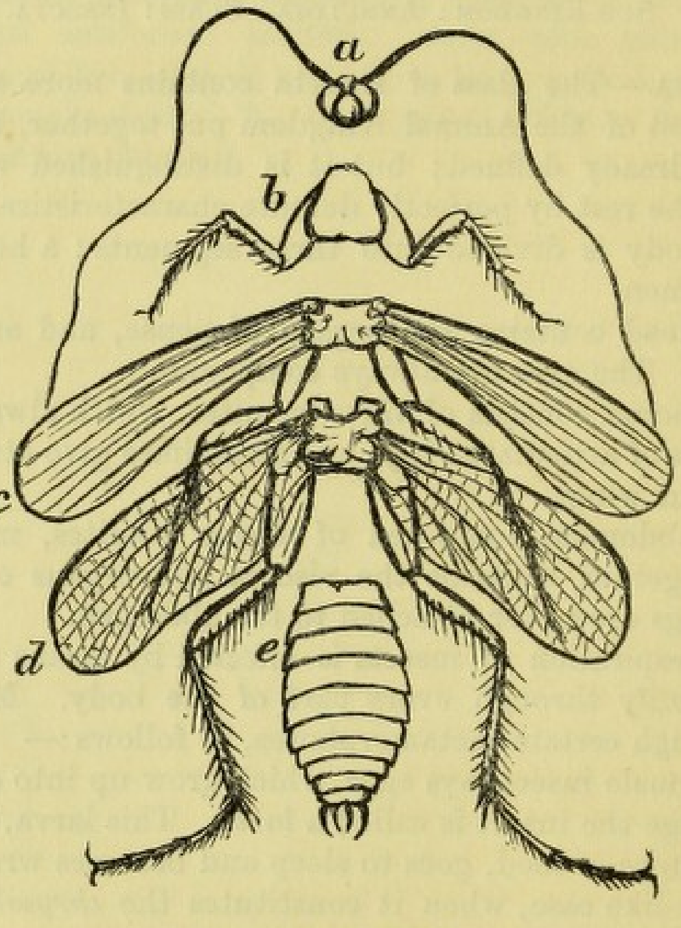


DIAGRAM OF INSECT.

Blatta orientalis. *a.* Head with compound eyes and antennæ. *b.* Prothorax with first pair of legs. *c.* Mesothorax with second pair of legs and first pair of wings. *d.* Metathorax with third pair of legs and second pair of wings. *e.* Abdomen without limbs, but carrying terminal appendages which are subservient in reproduction.

in both is arranged in the following manner:—Two long and large secreting cæcal tubes are situated on either side of the alimentary canal; these terminate in excretory ducts, which pass up to terminate on the under lip, at the base of a little elevation called the *fusulus*, or *spinneret.* When spinning, this fusulus is placed against any object, and the head being withdrawn, the tenacious fluid of the ducts is drawn out; this being exposed to the air, rapidly loses its fluid parts, and becomes converted into a thread of silk.

Insects are sometimes divided into two great groups, by the description of mouth which they possess.

Some possess a formidably armed mouth, provided with powerful jaws, and capable of biting, boring, tunnelling, &c. This is the *mandibulate* mouth, and is illustrated by beetles, dragon-flies, &c. The second group possesses a mouth adapted to suction ; it is arranged in the shape of a long, coiled, hollow tube, which is covered by spiral muscular fibres, running in opposite directions, and so enabling it to suck up the juices of flowers. This is the *haustellate*, or suctorial mouth. This group is illustrated by the Butterfly, &c.

Two very interesting varieties of *Agamogenesis* are met with among Insects. In one variety the female, *e.g.* the silkworm moth, lays fruitful eggs without any sexual intercourse. In the genera which multiply in this way the females never acquire wings. In Bees a modification of this plan is met with : the queen bee (the only perfect female in the community) has coitus with a drone once in four or five years, the drone paying for the honour of her embrace with his life ; the immense number of eggs the queen-bee gives birth to during this period of four or five years are all impregnated by this single act of sexual intercourse. Another form of Agamogenesis is met with among the Aphides. An aphis, when supplied with warmth, commences to produce, and goes on producing, for an indefinite period of time, fresh aphides, which, like their single parent, are all true neuters.

There are three kinds of insects whose *parasitism* is so interesting as to be worth mentioning :—

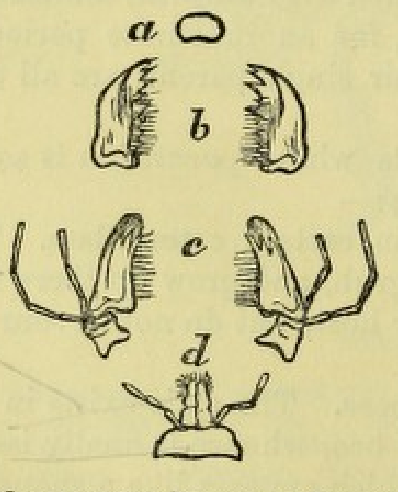
1. The Ichneumon is parasitic in certain caterpillars. The eggs are laid in the body of the grub, and grow up there into larvæ ; the larvæ then devour their host, but do not devour his viscera or each other.

2. The Stylops is parasitic in bees. The male exists in the pupa stage within the body of the bee, whence it finally issues as a minute imago. The female, which appears like a shapeless bag, protrudes a rudimentary head from the body of the bee, and in this situation is impregnated by the flying male.

3. The Sphex, a species of wasp, stings some large insect, such as a beetle, in the thoracic ganglia, and, having paralysed its victim by this means, it deposits its offspring within the unresisting body of its victim, who devour the internal viscera at their leisure.

The wings of insects, when present, are developed from the tergal elements of the second and third thoracic somites. Integument chitinous and moved by muscles. The thorax is composed of three segments, called respectively, *prothorax*, *mesothorax*, and *metathorax*. The legs of insects are formed on something like the vertebrate plan. The first or proximal portion is termed the *coxa*, or hip; this segment unites with the thorax by a ball and socket joint, permitting free movement in nearly every direction. Next we have the *femur*, or thigh; and to this succeeds the *tibia*, corresponding to the leg of higher animals. Lastly we have the *tarsus*, or foot, which may consist of one, but usually of many segments, the ultimate portions being provided with a variety of apparatus to assist in locomotion. Thus, in some, the tarsus is terminated by hooks, in others by suctorial discs which enable the creature to climb easily up a pane of glass, or to run in an inverted position. The wings, which are membranous vesicles penetrated by the tracheæ, may be looked upon as tracheal expansions; they are, however, essentially organs of flight, as the insect does not necessarily die if they are removed, respiring, under these changed circumstances, by the surface of the body. When the anterior wings are chitinous, or leathery, they are called 'elytra;' sometimes the posterior pair are converted into filaments, called 'halteres,' or 'poisers.' When a sting is present, it is generally carried near the tail, which also is connected with the generative organs.

Fig. 24.



MASTICATORY MOUTH OF INSECT.

a. Labrum or upper lip. *b*. Labium or lower lip, with jointed palpi. *c*. Maxillæ with jointed palpi. *d*. Mandibles.

The mouth of insects is a most complex and variously modified apparatus, but, as has been mentioned above, is broadly divisible into two distinct kinds, the masticatory and the suctorial mouth. The *masticatory* mouth consists of an upper lip, or *labrum*, a pair of biting jaws, or *mandibles*, a pair of chewing jaws, furnished with palpi, or *maxillæ*, and a lower lip, formed by confluent maxillæ, also provided with palpi, or the *labium*, of which the lower fixed part is called the *mentum*, and the upper movable part the *ligula*. The *suctorial* mouth is formed by the great development of the maxillæ, each of which forms half a tube, the two cohering to form a spiral trunk, the *proboscis*, which serves to suck or pump up the juices of flowers. The labium is very small, but the labial palpi are very large. Some of the Hemiptera, or honey suckers, have their mandibles and maxillæ modified, to form four needles, or lancets, with a long tubular labium. An arrangement similar to this is met with in the common house-fly.

In recapitulation, then, the mouth of insects possesses four laterally working or transverse jaws in addition to the upper and lower jaws. The upper and lower jaws, or the labrum and the labium, often only serve to close the mouth, and are called the 'lips,' the upper pair of transverse jaws are the 'maxillæ,' the lower the 'mandibles.' Both the mandibles and the labium, as a rule, support palpi, which are organs of sensation. From this it will be seen that there are many points of resemblance between the mouth of Insects and the mouth of Crustaceans.

The immense class of Insects is often broken up into great divisions or sub-classes, according to their metamorphosis being complete, incomplete, or absent; thus those who go through no metamorphosis are the *Ametabola*, those with a partial metamorphosis are the *Hemimetabola*, and those with a complete metamorphosis the *Holometabola*.

	Orders	*Examples*
AMETABOLA	1. Anoplura	Lice.
	2. Mallophaga	Bird Lice.
	3. Thysanura	Spring Tails.
HEMIMETABOLA	4. Hemiptera	Plant Lice, Cicadas, Boat Flies.
	5. Orthoptera	Crickets, Grasshoppers, Cockroaches.
	6. Neuroptera	Dragon Flies, Caddis Flies, Termite Ants, &c.
HOLOMETABOLA	7. Aphaniptera	Fleas.
	8. Diptera	House Flies, Forest Flies, Gnats.
	9. Lepidoptera	Butterflies, Moths.
	10. Hymenoptera	Bees, Wasps, Ants.
	11. Strepsiptera	Streps.
	12. Coleoptera	Beetles, Weevils, &c.

As already stated, another classification depends upon the character of mouth, and is as follows:—

	Orders	*Examples*
MANDIBULATA	1. Coleoptera	Beetles.
	2. Dermoptera	Earwigs.
	3. Orthoptera	Crickets.
	4. Neuroptera	Dragon Flies.
	5. Trichoptera	Caddis Flies.
	6. Hymenoptera	Bees.
	7. Strepsiptera	Stylops.

HAUSTELLATA	8. Lepidoptera	Butterflies.
	9. Diptera	Flies.
	10. Homoloptera	Forest Flies.
	11. Aphaniptera	Fleas.
	12. Aptera	Lice.
	13. Hemiptera	Bugs.
	14. Homoptera	Plant Lice.

The former, depending as it does upon embryological characters, is the more reliable of the two.

Sub-class. AMETABOLA.

Order 1. **Anoplura** (ἄνοπλος, unarmed; οὐρά, tail). Lice. 'Pediculi.' Minute aptera. Mouth suctorial, but is also furnished with sharp setous bodies which resemble mandibles; two or no simple eyes; parasitic. They are flat, semi-transparent, jointed little creatures, with three short pairs of thoracic legs, each terminating in a hook. The stigmata may be plainly seen. Ocelli are present on the head. Most animals, including man, are the occasional hosts of Pediculi.

Order 2. **Mallophaga** (μαλλός, a fleece; φάγειν, to eat). Bird Lice. Minute parasitic apterous insects. Mouth masticatory, by which they destroy the down and soft feathers of birds, on which they are chiefly found.

Order 3. **Thysanura** (θύσανος, tassel; οὐρά, tail). 'Spring Tails,' or Poduræ. Small aptera. Mouth masticatory. Jointed organs of locomotion, situated on abdomen, formed of forked caudal appendages or bristles, by means of which these creatures are enabled to make astonishing leaps. The common Podura is a very favourite microscopic object, on account of the beautiful pearl-like scales with which its body is covered.

Sub-class. HEMIMETABOLA.

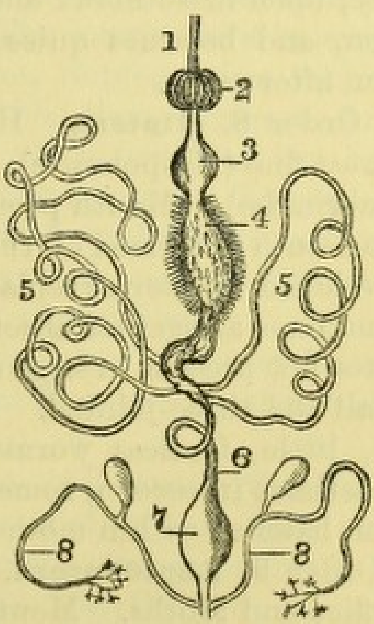
Order 4. **Hemiptera** (ἡμι, half; πτερόν, wing). Plant Lice (Aphides). Field Bugs (Pentatoma). Boat Fly (Notonecta). Cochineal insects (Cocci), and the Cicadas. Mouth suctorial; labium prolonged into proboscis; eyes compound; ocelli; two pairs of wings, or wingless. In the Homopterous division of this order, including Cicades, Aphides, Scale Insects, and Lantern Flies, the anterior pair of wings are entirely membranous, and the wings are folded over one another when not in use. Prothorax shorter than mesothorax; antennæ small, and five-jointed; ovipositor with three-jointed blades. The Cochineal insect is of great importance. It feeds on different species of cactus, and from it some of our finest red dyes are procured, and also the substance called shell-lac. In the Heteropterous division, including the land and water bugs (Geocorisæ and Hydrocorisæ), the anterior wings are membranous at free edge;

chitinous at base; antennæ moderate, and five-jointed; prothorax largest thoracic segment.

Order 5. **Orthoptera** (ὄρθος, straight; πτερόν, wing). Crickets (Achetina). Grasshoppers (Gryllina). Locusts (Locustina), and Cockroaches (Blattina). Mouth masticatory; wings four, or wanting; anterior pair small and coriaceous; filled with reticulate nervures; posterior wings of different material—hinder part is transparent, and folds like a fan; legs variously modified; powerful jumping organs in *grasshoppers;* raptorial in *mantis;* cursorial in *locusts.* The latter are very destructive insects, particularly migratory locusts. A few hours may bring vast hordes of this terrible scourge upon a district; a few more and they are gone. Some of the creatures belonging to this order are remarkable for the peculiar sounds they produce. These noises are caused by the rapid friction of the long hind legs against the wing. The sound produced by the grasshopper is believed to be the highest known musical note.

Order 6. **Neuroptera** (νεῦρον, cord; πτερόν, wing). Dragon Flies (Libellulidæ). Caddis Flies (Plioganeidæ). May Flies (Ephemeridæ). Ant-Lion (Mygonelis), and the Termite Ants. Mouth masticatory; wings four, nearly equal; exaphonous; nervures freely inosculate. Larva an active hexapod with prolegs.

Fig. 25.



Digestive System of Insecta.

Carabus auratus.—1. Œsophagus. 2. Crop. 3. Gizzard. 4. True digestive stomach. 5. Coiled tubes, probably homologous to the liver. 6. Intestine. 7. Cloaca. 8. Excretory tubes, probably renal.

The Termites, or White Ants, inhabit tropical countries, especially the neighbourhood of the Amazon. They form communities, and build large structures, called 'Termitaria,' which are from four to five feet in height, and as much in breadth. Each Termitarium contains a great many chambers, and communicates with the exterior by long covered ways. The whole structure is plastered together by the saliva of the builder insects. The Termites carry the principle of the division of labour to an extreme degree; certain members being devoted to the defence of their habitation, called 'soldiers,' others, called 'workers,' being absorbed in the building and repairing of the citadel in which they dwell, and a single male and female being solely occupied in propagating their species. Both the workers and the soldiers are 'neuters,' that is, neither perfect males nor perfect females, and only differ from one another in the armation of their head; thus the mandibles of the soldiers are converted into formidable hooked weapons, while in the workers they are rudimentary organs. The king and queen are always kept strictly guarded in the interior of the Termitarium, and are fed on a special and peculiar food. Both are wingless, though in their early condition they possess wings, and in their turn give rise to many winged progeny, who become kings and queens of other colonies in due time. Besides these offspring, however, a great number of neuters are born to the queen, who are as quickly removed to small cells of the Termitarium by the workers. These grow up into workers and soldiers, but are distinct from each other from the first, though produced from similar ova, and fed on similar food.

Sub-class. HOLOMETABOLA.

Order 7. **Aphaniptera**. Fleas (Parasitic annulosa). Mouth suctorial, but furnished with lancet-shaped mandibles and a sharp styliform filament for piercing the skin; wings rudimentary, upon mesothorax and metathorax. The larva spins a cocoon, and becomes quiescent in a fortnight. Imago emerges soon afterwards.

Order 8. **Diptera.** House-flies (Muscæ). Gnats (Culicidæ). Forest flies (Hippoboscæ). Crane flies (Tipulidæ), and Gad flies (Gabrinidæ). Mouth peculiar, placed on under surface of head; the mouth is formed of tubular labium. Anterior wings alike developed; posterior replaced by 'halteres' or 'poisers.' Wings sometimes altogether absent; ocelli and compound eyes; nervures not present in large numbers; wings transparent; antennæ small and three-jointed. Larva (common on meat, &c.), white fat, little, footless worms, with an indistinct head. Larva sometimes in cocoon, sometimes chrysalis case. Eggs sometimes even hatched within mother, *e.g.* Pupipara.

Order 9. **Lepidoptera.** (λεπίς, scale; πτερόν, wing). Butterflies and Moths. Mouth a coiled tube, like a whip, perhaps measuring an inch in length, formed of maxillæ, surrounded by muscular walls, for drawing juices from flowers; palpi hairy and large; labium and mandibles rudimentary. Wings, four in number, covered with scales, arranged in an imbricated manner; nervures longitudinal; antennæ many-jointed. Larva is formed in caterpillars of thirteen segments. Mouth masticatory. The labium is pierced by *spinneret.* Behind the thoracic legs there are several soft-hooked abdominal legs or 'prolegs,' which are never attached to fourth, fifth, tenth, and eleventh abdominal segments.

The Diurnal Lepidoptera, or Butterflies, differ from the Crepuscular Lepidoptera, or Moths, in their wings being held erect when in repose, in the antennæ being knobbed, prolegs being always ten in number, and in the pupa being naked, angular, and fixed by anterior extremity : whereas in the Moth the wings are horizontal in repose, the antennæ are fusiform, the hinder wings are hooked by a spine (reticulum) into the under surface of the anterior wings, and the pupa is never angular. In the true nocturnal Lepidoptera again the pupæ are generally encased in a cocoon.

Order 10. **Hymenoptera** (ὑμήν, membrane ; πτερόν, wing). Bees, Wasps, Ichneumons, Saw Flies, Ants. Mouth masticatory ; maxillæ and labium often suctorial ; eyes compound, with three additional ocelli ; antennæ filiform. The hinder part of abdomen has three additional segments, two forming a case for the third, called the *ovipositor*, which is sometimes a boring organ or *terebra*, or sometimes a sting or *aculeus*. Many Hymenopteræ are social—for example, Bees.

The colony of Bees is formed of the perfect female, called the 'queen bee,' many perfect males, the drones, and a swarm of sexless bees, the neuters or workers. The queen-bee is impregnated by a single congress with a drone, impregnation taking place in a bag called the *spermotheca*. She then begins to lay eggs, some only of which are fertilised ; these fertilised ova become perfect females, the queens of future colonies ; the rest of the ova are hatched parthenogenically, and produce the neuters and the drones. The ova are all placed in cells of different sizes, and the female ova are fed with a special food.

The 'vespiary' of the Wasps, like the hive of Honey Bees, contains males, females, and neuters, but the perfect males work equally with the neuters.

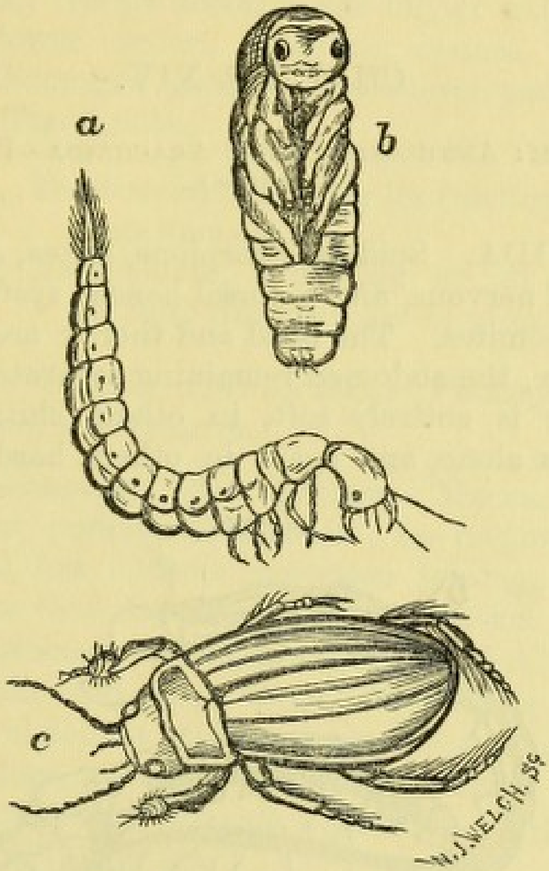
Ants (Formicidæ) also found colonies, and consist of males, females, and neuters. The metamorphosis of ants is very curious. Males and females are both winged ; after impregnating the female the males die, and the females lose their wings, but in their fallen state alone become queens—they 'stoop to conquer.' In many ant-colonies the neuters consist of two classes, 'the workers,' who do all the building and storing of the little town, and 'the soldiers,' who defend the works. Two of their customs are so singular as to demand mention, viz., their slave-trade, and their treatment of the Plant Lice or Aphides.

In many ant-colonies the 'soldiers' sally off in quest of slaves, whom they capture in the pupa stage from neighbouring colonies. These slaves are then brought off, and become most devoted servants, frequently doing the entire work of the colony; even feeding their masters, who are too helpless to feed themselves. Such is the case with the *Formica rufescens* of France. In other colonies, as *e. g.* the *Formica sanguinea*, common in the south of England, the males and slaves work together, but when the colony sends off a slaving expedition the masters go alone. Migrating they carry the slaves in their mouths. The slaves are smaller than their captors, and of a different genus, *e.g.* the Formica fuscaris is the slave of formica sanguinea. Their intercourse too with the Aphides is very curious. The Aphides, or Plant Lice, are furnished with an abdominal gland, which secretes a viscid, milk-like fluid, which escapes from a duct on the under surface of the body. Of this secretion Ants are very fond, and are in the habit of seeking these Plant Lice, or even *keeping* them in their colonies for the purpose of milking them; this they do by caressing the abdomen of the Aphides with their antennæ, which causes a drop of milk to exude, which the Ant greedily swallows.

Order 11. **Strepsiptera** (*στρέψις*, a twist; *πτερόν*, a wing). Minute, chiefly parasitic, insects, the males being differently formed to the females. The female is a wingless grub, with a horny head, and is parasitic. The males are winged, and active. Anterior wings rudimentary; posterior wings folded, like a fan, and membranous. Their peculiar parasitic habits have been before briefly referred to. The best example is Stylops.

Order 12. **Coleoptera** (*κολεός*, a sheath; *πτερόν*, a wing). Beetles. The mouth is a formidable masticatory organ. Anterior wings dense and chitinous; elytra form cases for posterior wings, which are sole agents in flight. Both elytra and other parts of body often covered with a bright metallic lustre. Eyes compound, and ocelli at base of antennæ. Antennæ various; generally eleven-jointed. The tarsus is generally formed of five joints, never more, the last being double-hooked. Pupa often in cocoon, and parts of wings can always be made out in pupa stage. Larva grub-like, with a horny head. The Coleoptera are nearly all rapacious in their habits, the majority feeding on decaying animal and vegetable matter, but some feeding on living animals, the Coccinella or Lady-bird, for instance, living on green Aphides. We may look upon this order to a great extent as the scavengers of the earth. This habit is best exemplified in our own country by the burying beetle, Necrophorus, who will bury any portion of flesh or dead animal which may be lying on the surface of the earth. In the buried flesh the creature lays its eggs, and the putrefying substance affords nourishment for the larvæ when hatched. The Watchman beetle, Geotrupes, in the same manner buries the excrement of living animals. The metamorphosis of Coleoptera is figured in the annexed diagram.

Fig. 26.



METAMORPHOSIS OF WATER-BEETLE (*Dytiscus marginalis*).

a. Larva. *b*. Pupa. *c*. Imago.

Terms used in describing the Tarsus of Insecta.

A. Pentamera, five-jointed tarsus.

B. Heteromera, five-jointed tarsus; anterior four-jointed, posterior do.

C. Tetramera, four-jointed tarsus.

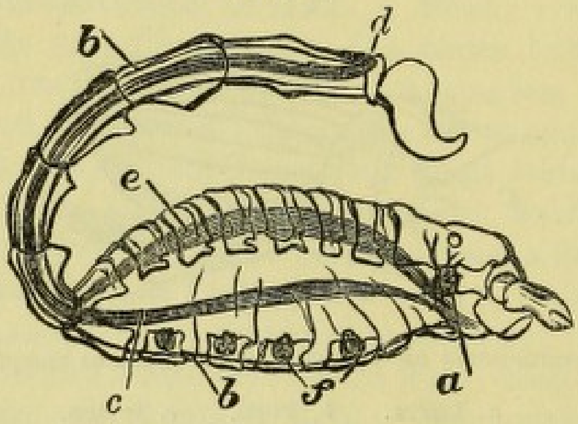
D. Trimera, three-jointed tarsus.

CHAPTER XIV.

SUB-KINGDOM: ANNULOSA—CLASS: ARACHNIDA—PHYSIOLOGY OF ANNULOSA.

ARACHNIDA. Spiders, Scorpions, Mites, &c. Annulosa, with a ventral nervous, and a dorsal hæmal system, and a body consisting of somites. The head and thorax are welded into a cephalo-thorax, the abdomen remaining separate and free. The skin in some is entirely soft, in others chitinous upon the cephalo-thorax alone, and again in others hard and chitinous

Fig. 27.



ARACHNIDA.—DIAGRAM OF SCORPION TO SHOW ITS MORPHOLOGY.

a. Cephalic ganglion. *b*. Line indicating position of ganglionic chain. *c*. Intestine. *d*. Anus, beyond which is the tail carrying the sting. *e*. Position of heart. *f*. Pulmonary sacs.

over the entire body. Limbs, when present, never exceed four pairs; two pairs (the anterior) alone developed. Eyes always sessile and simple. Breathing aërial, and consequently never by branchiæ, but by branched tubes, 'tracheæ,' or respiratory sacs, or both, formed by involution of integument. The tracheæ are kept patent by being lined with a spiral thread of chitine; they open upon the surface by stigmata. No tergal elements are found in somites, but the carapace is formed by coalescence of epimera. Venter protected by shield, formed by sternal elements, to which legs are attached. Mouth suctorial, with lower lip (labium), sometimes upper lip (labrum), two mandibles for prehension, and two maxillæ with palpi. No wings. Many Arachnidæ possess poison glands, which are situated at the base of hollow mandibles; the mandibles terminate in hooks. In others, *e.g.* in Scorpions, the mandibles end in chelæ. Alimentary canal simple, almost straight. Spiders live on the juices of animals. Heart dorsal in the higher order of Spiders; no vessels in lower order. Nervous system has cephalic, thoracic, and abdominal ganglia, well developed. Sexes distinct, except in Tardigradæ.

Divisions: A. *Trachearia*, breathing by tracheæ; never more than four ocelli.

,, B. *Pulmonaria*, breathing by air-sacs, with or without tracheæ; six or more ocelli.

A. *Trachearia* contain four orders:—Pautopoda, Linguatulina, Tardigrada, and Acarina.

Order 1. **Pautopoda.** Sea Spiders. Marine, but doubtfully Arachnidan; perhaps Crustacean; no respiratory organs; alimentary canal has curious processes joining on to limbs. Crustacean rather than Arachnidan in respiration; Arachnidan rather than Crustacean, in the fact that the limbs are four in number. Maxillæ and palpi large; female has sac for ova. Sexes distinct; abdomen rudimentary. Sea Spiders are provided with long legs, and are often found lurking under stones at low tide. *Pycnogonum littorale*, a parasite of fish, is the commonest example of this order.

Order 2. **Linguatulina,** or Pentastomida. Parasites found in frontal sinuses and lungs of Vertebrates. Very like Tæniæ in possessing no external organs when adult; when young, however, they have four limbs.

Order 3. **Tardigrada,** sloth animalcules; found in moss and gutters. Monœcious; abdomen undeveloped. No heart, or blood vessels, or respiratory organs. Four rudimentary limbs; a suctorial mouth, with rudimentary jaws.

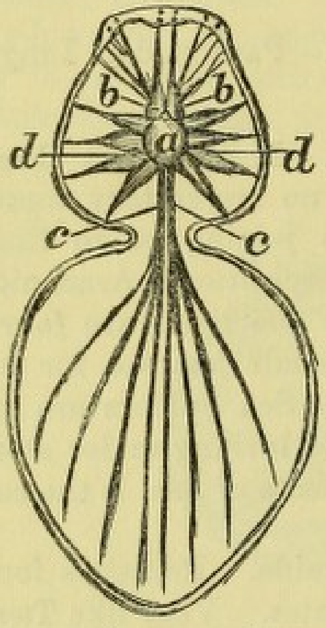
Order 4. **Acarina.** Parasitic and free Arachnida, comprising Water Mites, Ticks, and Mites; in this order too the *Acarus* or *Sarcotes Scabiei*, or 'itch' insect is found. Cephalo-thorax and abdomen one. Mouth suctorial. Four pairs of legs for walking. In the 'itch' insect the two anterior legs have suckers, and the posterior have bristles. The Ticks, *Ixodes*, have a 'rostrum' or 'beak,' which pierces the skin, by which means they fix themselves to sheep, dogs, oxen, &c. *Demodex folliculi*, a little parasite, found in sebaceous follicles of man, belongs also to this group.

Division B. *Pulmonaria.* Scorpions and large spiders. Respiration by pulmonary sacs alone, or by sacs and tracheæ. The eyes six in number. Abdomen distinct.

Order 1. **Pedipalpi,** or Arthrogastra. Tracheal breathing Arachnidæ with a well-segmented, but not clearly distinct abdomen.

Scorpionidæ (fig. 27), a formidable family, common in hot countries. The last segment of abdomen ends in a remarkable hook-like claw, perforated at the base, and connected with a poison gland; this is carried like a shield, curled over the back. Abdomen twelve somites; four pairs of walking feet on thorax. Six, eight, or twelve eyes. Palpi large and chelate; mandibles also chelate. Pulmonary sacs, four on each side, open by stigmata on ventral aspect.

Fig. 28.



NERVOUS SYSTEM OF SPIDER.

To show its extreme condensation in this class.

a. Central mass. *b b.* Encephalic ganglia. *c c.* Nerves going to the abdomen. *d d.* Thoracic ganglia and efferent nerves.

Thelyphonidæ. Like spiders, but no spinnerets; cephalo-thorax clearly separated from abdomen. Palpi movable; claws not chelate. No sting on the tail.

Phalangidæ. Harvest Spiders. Long hooked palpi and very long ungainly legs.

Cheliferidæ. Book Scorpions. The palpi large and chelate; found between the leaves of books.

Solpugidæ (includes Galeodes). Abdomen separate from thorax. Mandibles chelate. Feet furnished with palpi.

Order 2. **Araneida.** Spiders. Soft, globular, unsegmented abdomen connected with cephalo-thorax by a peduncle. Respiration by sacs (two or four) and tracheæ. Eyes, six or eight, simple. Mandibles hooked and hollow, perforated by a poison duct, leading to a gland situated at their base. Palpi never chelate. The webs of spiders are spun by the aid of two secreting glands and spinnerets, just like the cocoons of silk-worms, a process which has already been described. *Reproduction*; no metamorphosis; sexes distinct; male, prior to sexual congress, applies his palpi to the efferent ducts of testes situated on the abdomen, and draws thence a supply of spermatozoa; he then uses his palpi as an intromittent organ, and the spermatozoa there contained then pass to the vulva of the female. The commonest examples of this order are the *Epeira diadema* or geometrical garden spider, and the *Tegenaria domestica* or house spider.

Physiological Processes of Annulosa.

The physiological functions of Annulosa have been incidentally referred to in the preceding paragraphs, but it is desirable to supplement these scattered notices by a brief summary of the more important processes.

Digestion.—In perfect Insects the alimentary canal possesses a crop, a gullet, a stomach, large and small intestines, and a cloaca, common to it and the reproductive organs. In the larvæ of Insects the alimentary canal is a simple tube, held down by a mesentery. In Myriapoda the alimentary canal is short, straight, narrow, and provided with saccular dilatations, which serve for stomachs. In Arachnida the digestive tube is still shorter ; there are often four pouches appended to the stomach, and the intestine dilates before terminating.

The Crustacea have a short gullet, provided with calcareous particles which serve for teeth, and a powerful muscular apparatus which serves for a gizzard : the intestine is short, straight, and simple.

The Annelida have a straight tube provided with cæcal diverticula.

Circulation.—In the larger Annulosa, as *e.g.* in the higher Crustacea, a true heart is found, consisting of a single strong muscular ventricle, which pumps the blood all over the body, and is therefore *systemic.* The blood is not contained in proper vessels, but is propelled into lacunæ or spaces, whence it is collected into large veins, which send it to the branchiæ for purification; from the branchiæ the purified blood is collected by branchio-cardiac veins and poured into a venous sinus above the single ventricle, into which it passes, and so completes the circulation. In insects we find a numerously-segmented dorsal vessel, which contracts rhythmically and propels the blood through lacunæ to every part of the body, whence it is returned into a large venous sinus placed above the dorsal vessel. In Arachnida and Myriapoda the same plan obtains, but the number of contractile segments varies widely. In Annelida there is no true contractile vessel of any kind, but certain tubes exist, called pseudo-hæmal vessels, which contain a corpusculated fluid, which circulates throughout the body, and communicates with the exterior.

These tubes have close analogies to the 'water-vascular' system of Annuloida. They are always lined with cilia.

Respiration.—Many Annulosa respire atmospheric air; in others the respiration is aquatic.

Aërial Respiration.—In the air-breathing Annelida small sacculi are found in each segment beneath the envelope communicating with the exterior. In Myriapoda two small hard-walled sacs are found in each segment, which communicate with the exterior by means of fine tubes called spiracles. In Arachnida a similar arrangement is met with; in some the air-sacs are tubular. In Insects the respiration is very perfect, and is what is called *tracheal.* Each segment possesses spiracles which conduct, after passing for a short distance, into two longitudinal tubes, which run the whole length of the body, and from which secondary tubes are given off, which ramify through every part of the body, piercing even the nervous ganglia and viscera. These tubes have firm walls, and are always patent: their patency being secured by the very character of their structure. Each tracheal tube has membranous homogeneous walls, but within these walls is found a spiral thread, which is wound so closely as itself to form a wall—these spiral threads are present in tracheæ of extreme minuteness. In the wings we find the tracheæ placed between two sets of small vessels, one answering to arteries and the other to veins.

Aquatic Respiration.—The Crustacea and the Tardigrade Arachnida are the only Annulosa which respire by means of gills or branchiæ. These branchiæ are enclosed in proper branchial cavities, and present the form of flattened laminæ. They are rather numerous in some Crustacea; *e.g.* the lobster has twenty-two branchiæ on each side. The water is kept in active motion by means of special flappers, which are made out of some of the abdominal segments.

Some of the Crustacea, such as the wood-lice and land crabs, though provided with gills, are drowned if kept in water. In these animals, the gills are merely kept moist by the watery vapour contained in the atmosphere.

The respiration in Annelida is also aquatic. The branchiæ are either branched or tufted, and are situated sometimes on every segment of the back, as in *Nereis*, or round the head only, as is the case with *Serpula*, or more or less concealed, as in *Aphrodite*.

Nervous System.—The comparatively large supra- and subœsophageal ganglia give off nerves to the eyes, to the auditory apparatus, to the antennæ, where the sense of touch is located, to the antennulæ, where the sense of smell is supposed to reside, and sensory nerves to the entire body. These ganglia are the seats of sensation, of sensory-motor actions, and, to a certain extent, of volition. They superintend and regulate, as the brain of higher animals does, all the various movements of the body. The wonderful 'consensual' actions of bees and spiders are dependent upon these ganglia for their due performance. Small cords pass from these ganglia to the alimentary canal and viscera, which by some (Marshall) are held to be representative of the sympathetic system, while others assert (Huxley) that the homologue of the vertebrate sympathetic system is to be found in the principal ventral gangliated cord of Annulosa. The function of this gangliated cord is automatic, and presides over the pure reflex actions of the animal.

Senses.—In the two preceding kingdoms, the organs of sense have been but poorly developed, and confined to those of sight and hearing—in Annulosa the senses are much more perfect. *The sense of touch* resides in the antennæ of some (ants), the palpi and feet of others (spiders).

The sense of taste resides in the pharynx.

The sense of smell resides in the antennæ in some, in the palpi in others.

The sense of hearing usually resides at the base of the first antennæ; in many insects a sac is found there filled with fluid, and containing otoconia.

The Sense of Sight.—Two kinds of eyes are found: the simple and the compound. The Orthoptera, Hemiptera, Neuroptera, and Hymenoptera have both simple and compound eyes. Some are destitute of eyes, as the neuter Termites. The simple eyes which are met with amongst Insecta have considerable analogies to the human eye. The whole is contained in a choroidal tunic, which bends down in front to form an iris and a pupillary opening; within this we find an expanded retina, a vitreous humour, and a small globular lens; there is no anterior chamber, the lens projecting directly against the smooth convex cornea. The impression of external objects produced by such an organ must necessarily be very vague.

The compound eyes have been already described.

The eyes of Myriapoda are not unfrequently conglomerate, *i.e.* simple eyes massed together—compound eyes are rarely met with; many are blind. The Arachnida have only stemmata. The Crustacea have both simple and compound eyes. The Annelida possess ocelli only.

CHAPTER XV.

SUB-KINGDOM: MOLLUSCOIDA—CLASSES: ASCIDIOIDA, BRACHIOPODA, POLYZOA—PHYSIOLOGY OF MOLLUSCOIDA.

MOLLUSCOIDA.

Definition.—Aquatic animals,—met with all over the world. The nervous system consists of a principal ganglion near the mouth, which is sometimes surrounded by a nervous collar. There is often only one opening, which answers both for inlet and outlet. When there are two apertures, the outlet is situated close to the gullet or inlet. The gullet always conducts into a very large and widely expanded pharynx: the outlet, when present, conducts likewise into a large space, called the *atrial chamber*.

They contain the following classes:—

1. Ascidioida.
2. Brachiopoda.
3. Polyzoa.

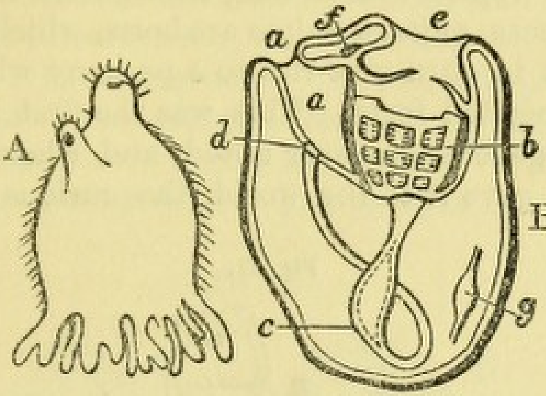
Class I. ASCIDIOIDA (ἀσκός, a bag; εἶδος like). Synonym *Tunicata.*

The Ascidioida are very singular-looking marine animals, somewhat resembling a double-necked little leather bottle at first sight. They are frequently grouped together in colonies, forming compound Ascidians. The gullet, surrounded by long ciliated tentacles, leads into an extremely wide and long pharynx, which occupies the greater part of the animal's body; this terminates at the lower and attached part of the body in an intestinal tube, which is flexed towards the heart, forming a *hæmal* flexure, as it is termed: after dilating into a stomach, it is continued up the body and opens near the oral aperture into a wide cavity, the *atrial chamber*, which terminates in a prolonged excretory tube. In all Ascidians, except *Appendicularia*, in whom no nervous system has been detected, the chief ganglion is placed between the oral and the anal apertures. The alimentary canal cannot be protruded through the oral opening.

All Ascidians possess a heart, which is unique in its structure. It is a muscular tube open at both ends. It contracts rhythmically, and first propels the blood from behind forwards ; it then pauses, and afterwards, contracting in the opposite direction, propels the blood from before backwards.

The covering of Ascidians is of a leathery consistence, and is secreted by a sort of mantle. They are always stationary. The integument of the Ascidians is composed of cellulose.

Fig. 29.

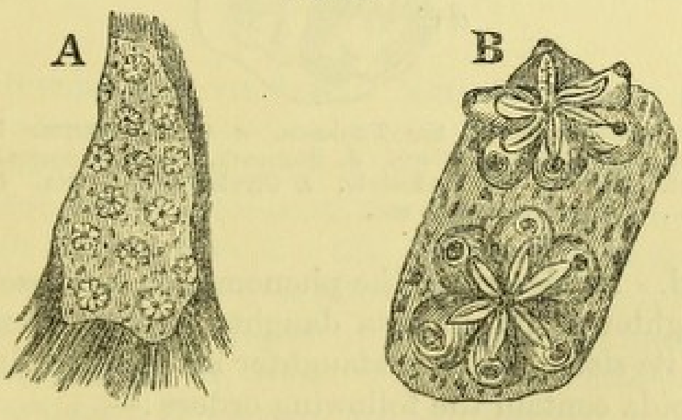


ASCIDIOIDA. MORPHOLOGY OF ASCIDIANS.

A. *Cynthia Papillosa*, one of the Tunicata. B. Diagrammatic section of a tunicary. *e.* Oral aperture. *b.* Pharyngeal or branchial sac with rows of ciliated slits. *c.* Alimentary canal making a hæmal flexure. *d.* Anus. *a.* Atrial Aperture. *f.* Nervous ganglion. *g.* Position of reproductive organs.

In *reproduction* Ascidians are monœcious, except *Doliolum* and *Appendicularia.* Young Tunicata swim, like tadpoles, by a

Fig. 30.

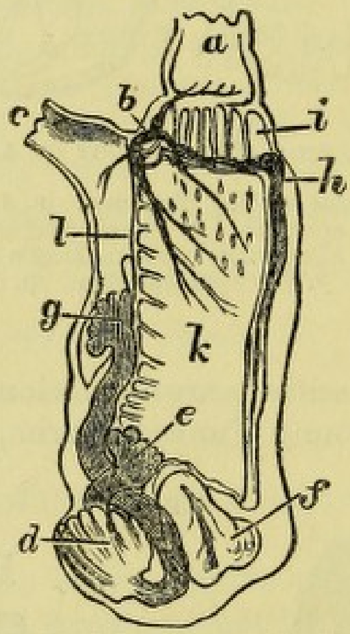


BOTRYLLUS, another group of Ascidians.

A. A cluster. B. Portion enlarged ; the same compounding has taken place as in fig. 1.

tail, which is of singular interest, inasmuch as some evolutionists see in this simple cellular structure the prototype of the *chorda dorsalis,* which is the principal characteristic of the vertebrate sub-kingdom, and thus the simple Ascidian is credited with a lineage of the most lofty kind. The caudal appendage of Ascidians, however, is not constant, *e.g.* the *Molgula tubulosa* does not possess any ; but when present it always contains the peculiar rod-like body which has given rise to so much curious speculation. The *Salpidæ* undergo an alternation of generations during their development : these curious compound Ascidians swim about the tropical seas in long transparent loosely adherent chains : from these, *solitary* Salpæ are born, which never become compound, but in turn give rise to a progeny which always assumes the aggregated form. This was the first instance of the alternation of generations ever noted, and when its discoverer, W. Chamisso, gave it to the world, the curious fact was long

Fig. 31.



Phallusia mentula, one of the Tunicata. *a.* Oral aperture. *b.* Nervous ganglion. *c.* Atrial aperture. *d.* Stomach. *e.* Œsophageal opening. *f.* Heart. *g.* Anus. *h.* Endostyle. *i.* Circlet of hooklets. *k.* Pharyngeal sac. *l.* Projections into sac.

disbelieved. He described the phenomenon in these words, 'A Salpa daughter is not like its daughter or its own mother, but resembles its sister, its granddaughter and its grandmother.'

Ascidioida contain the following orders :—

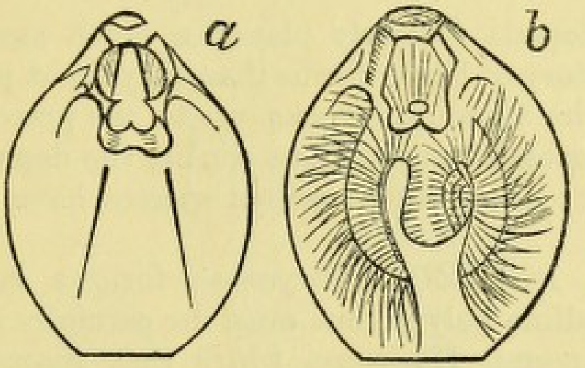
Order 1. **Ascidia Branchialia.** Branchial sac occupies nearly the whole of the body ; intestine lying on one side. Type-forms, *Ascidiadæ*, *Botryllidæ*, &c.

Order 2. **Ascidia Abdominalia.** Branchial sac small ; intestine quite behind it. Type-form, *Carellusia soliolum.*

Order 3. **Ascidia Larvula.** Permanent larval form, *Appendicularia.*

Class II. BRACHIOPODA are small bivalved marine Molluscoida: they inhabit the profound depths of ocean, and are strongly encased, to resist the great pressure of the water. Like the Ascidioida they are stationary; but they never form into colonies. The shell is secreted from a true mantle or pallium. There are two long ciliated arms on either side of the body. The gullet is placed in the centre of the body between the pallial lobes, and conducts into an intestine which, as a rule, ends in a cul-de-sac. The intestine has a *neural* flexure, *i.e.* it is flexed towards the nervous ganglion. The Brachiopoda possess a singular bilocular organ, called a *pseudo-heart,* which communicates with an atrial cavity near the mouth. The true heart is placed near the pseudo-heart, and is systemic in character.

Fig. 32.



BRACHIOPODA.

Terebratula vitrea. *a.* The shell with its loop. *b.* To show the ciliated arms.

Most of the Brachiopoda are fossil. The *Terebratula* and *Lingula* are the most common living species.

The ventral valve of the shell is the larger of the two, and is generally perforated by a foramen for the passage of the muscular peduncle which fixes it; the dorsal valve is never perforated. As a rule each valve is punctured by a number of little holes which run at right angles to the shell, and form a canal system for the passage of fluid. The *Rhynchonellida* do not possess this system. A peculiar set of branched inosculating tubes is formed between the lobes of the mantle called the 'Atrial system,' which has four pseudo-hearts connected with it; they connect the tubes with the perivisceral cavity on the one hand, and with the pallial cavity on the other. Each pseudo-heart is divided into two, a ventricle and an auricle, by a membranous septum. The ventricle communicates by a small opening with the pallial cavity, and the auricle by a large opening with the body cavity; the auricle and ventricle are also themselves united. The function of this atrial system is disputed, being looked upon variously as a respiratory, an excretory, and a reproductive apparatus. It cannot be regarded as a circulatory apparatus, as some Brachiopoda, e.g. *Terebratula*, possess in addition to the atrial system a distinct, unilocular, pyriform, dorsal heart.

Reproduction. Diœcious. Young, free, ciliated; adult, fixed. They do not pass through alternate generations.

Brachiopoda are divided into two orders:—

Order 1. **Articulata**: possessing a hinged shell, and a cœcally-ending intestine. Examples, *Terebratula* and *Rhynchonellida.*

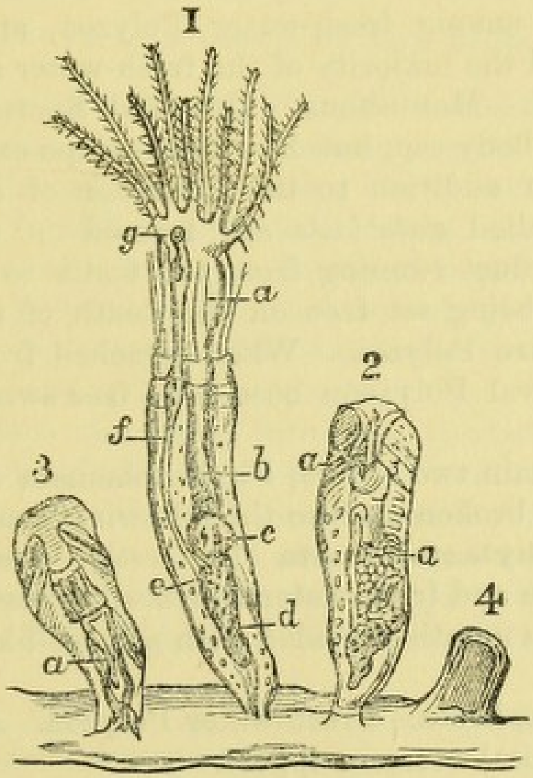
Order 2. **Inarticulata**: shell is not hinged, and the intestine is proctous; nearly all fossil, e.g. *Craniadæ*, *Discinidæ*, and *Lingulidæ.*

The Brachiopoda formerly played a much more important part in the history of living forms than they do at present; they extend from the Cambrian rocks up to the present time, and attained their greatest proportions during the deposition of the Silurian rocks. About 2,000 extinct species have been already described.

Class III. POLYZOA (Bryozoa) form a large body of compound coralline polyps, but must be carefully distinguished from the compound Hydrozoa which they resemble in many features. Some are fresh-water animals, as *e.g. Plumatella*, but the majority are marine in their habits. The Polyzoa are all very minute, even to being microscopic. The mouth is surrounded by long ciliated tentacles, which, constantly moving, draw in any passing nutriment. The gullet leads into a pharynx, and this into a distinct stomach, which ends in an intestine; the intestine, making a sharp, *neural* bend, ascends to terminate near the mouth. The chief ganglion is always placed between the two apertures. They multiply by gemmation and free ova. There is no distinct heart. All the Polyzoa are gemmiparously developed from a single zoöid. The separate zoöids of a Polyzoön do not communicate with each other as the zoöids of a compound Hydrozoön do, by the cœnosarc. The alimentary canal is loosely suspended within the Polyzoön, and can be protruded and retracted at will from the body by a set of distinct muscles. The zoöids of Polyzoa are generally freely charged with carbonate of lime, but may also be either corneous or fleshy.

The principal distinctions between the individual polypes of Polyzoa and Hydrozoa are the following:—In Hydrozoa there is no distinct alimentary canal, in Polyzoa there is; in Hydrozoa there is no distinct nervous system, in Polyzoa there is a well-developed nervous system: in Hydrozoa the reproductive organs are processes of the external wall, in Polyzoa they are contained within the body. Although these distinctions between Hydrozoa and Polyzoa are true, yet the distinction between them and the other division of Cœlenterates, the Actinozoa, is by no means so marked, and the relations of the two classes are indeed extremely close.

Fig. 33.



POLYZOA.

Bowerbankia densa. 1. The animal with its tentacula expanded. *a.* Pharynx. *b.* Œsophagus. *c.* Gizzard. *d.* True digestive stomach. *e.* Pylorus. *f.* Intestine. *g.* Anal aperture. 2. The same animal retracted into its cell. *a a.* Muscular fasciculi. 3. An imperfect gemma before the opening of the cell. *a.* Stomach. 4. A gemma budding from the common stem.

Many Polyzoa possess very curious appendages, connected with the ectocyst, and termed, from their close resemblance to the beak of a bird, *avicularia*; they are of microscopic proportions, but each consists of a movable mandible, and a cup with a horny beak which joins the mandible. In function they are probably protective, acting as defensive weapons; it is believed that they are in fact peculiarly modified zoöids. Besides these avicularia many Polyzoa possess other appendages, called *vibracula;* these are long bristles, connected by a movable joint to the Polyzoön, and serving like the avicularia for purposes of defence, and also, by sweeping the body of the Polyzoön free of noxious particles, for purposes of cleanliness. The ciliated tentacles which surround the mouth of a Polyzoön are non-retractile and form either a crescent or a circle ; in some, *e.g.* fresh-water Polyzoa, they are connected to the sac by a sort of funnel, called the *calyx.* The tentacles are supported on a disc, the *lophophore,* whose shape determines the classification of the Polyzoa, *e.g.* it is horse-shoe shaped in the Hippocrepian Polyzoa, circular in nearly all marine, and in Paludicella and Norvatella among fresh-water Polyzoa, and bilateral in Pedicellariæ and the majority of the fresh-water species.

Reproduction.—Monœcious. Ova and Spermatozoa escape loosely into the body sac, but how they escape externally is not determined. In addition to the formation of external buds, little gemmæ called *statoblasts* are formed on the funiculus, which is a little duct running from the testis to the stomach ; the statoblasts being set free on the death of the parent develop into mature Polyzoa. When detached from the parent colony, each larval Polyzoön becomes a free swimming ciliated embryo.

Polyzoa contain two orders, Phylactolæmata and Gymnolæmata, which are broken up into the following families :—

Order 1. **Phylactolæmata** (φυλάκτος, guarded ; λαιμός, throat). Marine and fresh-water Polyzoa, possessing a bilateral lophophore and a mouth provided with a valve-like organ, called an *epistome.*

Family 1. *Lophopea.* Fresh-water Polyzoa. Arms of lophophore free. Subcalcareous support.

2. *Pedicillinea.* Marine. Arms of lophophore united. Soft supporting framework.

3. *Rhabdopleurea.* Marine : cœnecium branched and adherent, with a chitinous rod on the adherent side, to which the polypides are fixed by funiculi. Lophophore horse-shoe shaped. Examples, *Hippocrepian Polyzoa.*

Order 2. **Gymnolæmata** (γύμνος, naked ; λαιμός, throat). No epistome. Lophophore circular.

Family 1. *Paludicellea.* Fresh-water. Polypides completely retractile. Subcalcareous. Evagination incomplete.

2. *Cheilostomata.* Marine. Polypides retractile, evagination complete. Sphincter closes orifice. Cells non-tubular. Calcareous, horny or fleshy.

3. *Cyclostomata.* Marine. Cells tubular. No sphincter. Calcareous.

4. *Ctenostomata.* Marine. Setæ surround cells. Cells distinct from common tube. Horny or fleshy.

The following terms are employed in describing Polyzoa :—

Polyzoarium or Cœnœcium, the entire colony, or entire dermal system. In Hydrozoa the equivalent term is Hydrosoma.

Polypides. Separate zoöids. In describing Hydrozoa they are called Polypes.

Cells. Chambers which contain polypides.

Physiological Processes of the Molluscoida.

Digestive System.—The Molluscoida are about the simplest animals in which a distinct alimentary canal is found, quite separate from the perivisceral cavity. In *Ascidioida* and *Polyzoa* the intestine is furnished with both mouth and anus ; in *Brachiopoda*, on the other hand, the intestine is generally aproctous. In some of the Polyzoa the stomach is truly gizzard-like.

Circulatory System.—In the *Ascidioida* the heart is at one time systemic, and at another respiratory. It possesses no valves, and pumps the blood into loose spaces or lacunæ. In the compound Ascidioida the vessels of one animal are connected with those of another through the common foot-stalk or 'stolon.' In the *Brachiopoda* the heart only contracts in one direction. The pseudo-heart of Brachiopoda is probably excretory in its function. The *Polyzoa* possess no distinct circulatory system.

Respiratory System.—In the *Ascidioida* the large pharynx is ciliated, and acts as a respiratory organ. It is separated from the exterior of the animal by a perivisceral space: the space has slit-like openings passing into it from the outside: through these apertures the water is admitted, holding oxygen in solution, and this easily passes by dialysis into the vessels of the pharynx, and so aërates the blood. In *Brachiopoda* the pallial lobes are the respiratory agents. In *Polyzoa* the perivisceral cavity is continued into the interior of the tentacles, where the blood is purified by the ciliary action which here takes place.

Nervous System.—The chief ganglion, which is the homologue of the pedal ganglion of Mollusca, sends filaments to the ciliated pharynx, and to the ciliated tentacles. Sometimes an eye-spot is developed on a filament which proceeds from it. The Molluscoida being nearly all stationary, the functions of this ganglion are of a reflex character, and have reference to respiration. It is also feebly sensory, and sensori-motor.

CHAPTER XVI.

SUB-KINGDOM: MOLLUSCA—GENERAL VIEW—CLASS: LAMELLIBRANCHIATA.

MOLLUSCA (*mollis*, soft). Synonym: *Heterogangliata* (Owen).

Definition.—This very large sub-kingdom is composed of animals of very various and irregular shapes, whose envelope is soft, but generally protected by a shell. The shell is secreted by the integumental covering which is termed the *mantle*. The nervous system is massed into three principal ganglia. One is situated in the head, another in the abdomen, and a third in the fleshy locomotive organ called the *foot*. These ganglia are termed respectively the *cerebral*, *parieto-splanchnic*, and *pedal*. The gullet is surrounded by a nervous collar, and commissural cords connect the cerebral and pedal ganglia. The blood is colourless, or nearly so. The heart is systemic, and consists of two cavities; the blood is contained in tubes. Except in the highest Mollusca there is no trace of an internal skeleton. The body is not segmented.

Respiration is sometimes aërial, sometimes aquatic, and consequently while some Mollusca have gills, others possess air

Fig. 34.

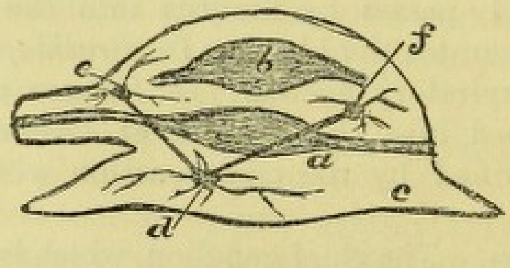


DIAGRAM TO SHOW THE GENERAL MORPHOLOGY OF MOLLUSCA.

a. Digestive System. *b*. Hæmal system. *c*. Foot. *d*. Pedal ganglion. *e*. Cerebral ganglion. *f*. Parieto-splanchnic ganglion.

sacs, analogues of vertebrate lungs. Mollusca all increase sexually. The shell in which they are enclosed may be single (univalve), or double (bivalve), or composed of many pieces (multivalve); whatever its shape it is closely connected with the function of respiration, and is formed as follows :—

The Growth of Shells.—Shells are secreted by the pallial covering or mantle of the mollusc. The shell extends in size by a secretion poured out from the free edge of the mantle, and therefore grows as the mantle increases. This part of the mantle is thick and glandular, and mixed with pigment-cells. The shell material is poured out, mixed with the pigment, in a semifluid state, which rapidly dries and hardens into shell on exposure to the air. The shell increases in thickness by a secretion poured out from the general surface of the mantle, and as there are no pigment-cells in this situation, the inner surface of the shell is perfectly white and pearly or nacreous. Some shells become spiral, because the collar, or free edge of the mantle, pours out its secretion much more from one part of its circumference than another, and the fact that sometimes one part and sometimes another becomes the actively secreting part of the mantle accounts for all the infinite variety of shapes which are met with amongst the shells of Mollusca. The principal ingredient of shell is *carbonate* of lime, of bone *phosphate* of lime. Three principal varieties of shell are described according to their density and construction.

1. The *nacreous shell*, or mother-of-pearl, formed by minute undulations of alternate layers of carbonate of lime and membrane.

2. The *fibrous shell*, formed by successive layers of prismatic cells.

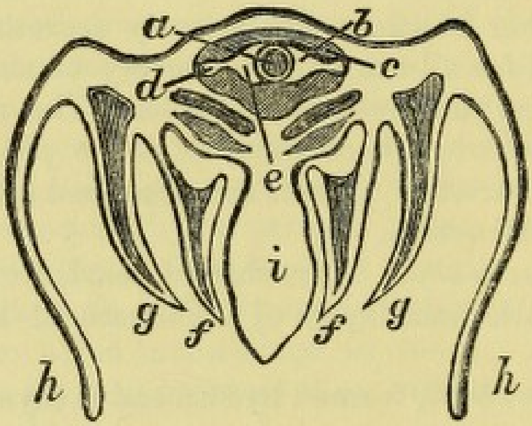
3. The *porcellaneous shell*, formed by many plates, arranged like cards on their edge.

All shells are covered by a membrane called the *periostracum*. Some Mollusca leave their shells untenanted by degrees, which are then called *decollated* shells. In the bivalve Mollusca each valve is a hollow cone, whose apex, termed the *umbo*, is turned towards that side on which the mouth is placed. The side towards the mouth is called *anterior*, and is the shorter; the other is the *posterior*, and is the longer of the two. The shell of bivalves is *hinged* on its dorsal side, the hinge being provided with interdigitations called *teeth*, and opens along the ventral border or base.

The *lunule* is the crescentic depression in front of the umbo. The shell is opened by a ligament and by a cartilaginous cushion or spring. The ligament, placed outside the shell and behind the umbones, is stretched when the shell is closed. The cartilage is inside the shell, close to the hinge, and passes from one valve to another, and is lodged in little pits. It is very elastic, and compressed when the shell is closed, so that if the restraining influence of muscular contraction be removed, the ligament and india-rubber-like cartilage force the shell open. The shell is also provided with two special adductor muscles—an anterior near the mouth, and a posterior on the neural side of the intestine. Sometimes only the posterior one is present (*Monomyaria*); more frequently both are present (*Dimyaria*).

Mollusca are divided into Lamellibranchiata, or headless Mollusca (Acephalous Molluscs), and into those which possess a distinct head (Encephalous Molluscs), the latter comprising the three classes Gasteropoda, Pteropoda, and Cephalopoda; the three latter also possessing a singular dentary organ, the *odontophore*, are sometimes termed 'Odontophora.'

FIG. 35.



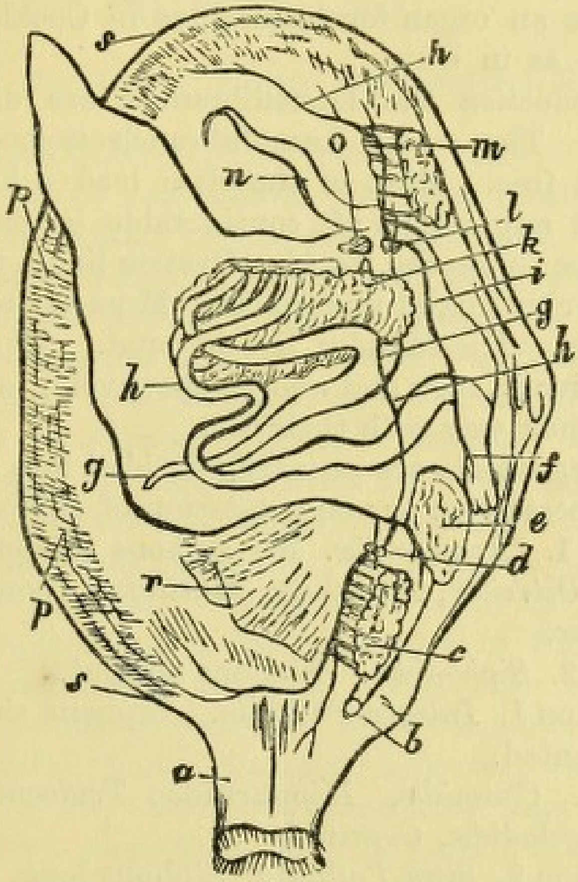
VERTICAL SECTION OF ANODON.

a. Rectum. *b*. Ventricle. *c*. Pericardium. *d*. Auricle. *e*. Ventricle. *f*. Inner gill. *g*. Outer gill. *h*. Mantle lobes. *i*. Foot.

Class I. LAMELLIBRANCHIATA (lamella, a thin plate; βραγχια, gills) (Conchifera). Bivalve shell fish, such as Oysters, Mussels, Cockles, Scallops, &c. Valves of shell right and left, not anterior and posterior, as in Brachiopoda.

Respiration by two pairs of laminar gills. *Intestine* performs a *neural* flexure. The liver is large, and often bright-coloured. Salivary glands not present. A blind sac contains a curious body called the *crystalline stylet*, which often opens into the stomach. *Heart*, always systemic, is either bilocular or trilocular; blood contained in arteries, capillaries, and veins. *Renal organs*, situated dorsally, are always present under the name of the *organs of Bojanus*; one is placed on either side of the pericardium, and is separated from its fellow by a venous sinus. The organ of Bojanus consists of a number of convoluted tubes, lined with a secreting epithelium, and a capillary plexus enclosed in the sac. The gill plates are kept erect by hollow vertical rods—they are often prolonged into tubes called *siphons*, which can be retracted or protruded at will by the siphonic muscles when siphons are present, the edges of the mantle are united, and the pallial margins of the shell present

Fig. 36.



MORPHOLOGY OF LAMELLIBRANCHIATA.

Mactra. *a*. Tube leading to siphons. *b*. Cephalic ganglion. *c* and *m*. Adductor muscles. *d*. Parieto-splanchnic ganglion. *e*. Ovary. *f*. *g*. *h*. Intestine. *i*. Stomach. The letter *h* on the left hand is placed upon the 'foot.' *k*. Liver. *l*. and *o*. Pedal ganglia. *n*. Nervous cord. *p*. Mantle. *r*. Position of gills. *s*. Shell.

an indentation, the *pallial sinus*, which gives rise to the term 'Sinupallialia,' for Lamellibranchiata so characterised.

The *mouth* is the only part of the head which is present. It is provided with four large palpi, but no other dental structure. The mouth leads to a gullet, the gullet to a stomach, to which succeeds an intestine, which after performing, as before stated, a *neural* flexure, pierces the wall of the heart, and terminates in an anus near the respiratory organs.

An organ formed by interlacing muscles, called the 'foot,' is present in most Lamellibranchiata, though not so large as in Gasteropoda. It is developed on the ventral aspect, and contains many longitudinal retractor fibres. In some it subserves locomotion (*e.g.* in Mactra); in the Mussels it is connected with a gland which secretes a glutinous material, the *byssus*, by which, after spinning it into threads, the foot fixes the animal to rocks or other objects. In others the foot is a burrowing organ, as in Pholades, Razor-shells, and Shipworms; or it may be an organ for leaping, as in Cockles, or act as a ploughshare, as in Unio.

In *Reproduction* the Lamellibranchs are diœcious, rarely monœcious. The young Lamellibranch is born viviparous, ciliated, and free. Most of the class lead a humdrum, quiet life, without any means of considerable locomotion; others, again, are free to see the world. Oysters lie on their side, with the ventral valve placed undermost. Mussels are fixed to rocks by the byssus. The Myades live in mud. Pholades and the Lythodomi live in rock and wood respectively, into which they have bored their way with their foot.

Lamellibranchiata are primarily divided into groups, according to their possession or non-possession of siphons.

Division 1. *Asiphonidæ.* No siphons present. Comprise Families of *Ostreidæ, Aviculidæ, Mytilidæ, Arcadæ, Trigoniadæ,* and *Unionidæ.*

Division 2. *Siphonidæ.* Siphons present.

Subdivision 1. *Integro-Pallialia.* Siphons short, and pallial line not indented.

Families. *Chamidæ, Hippuritidæ, Tridacnidæ, Cardiadæ, Lucinidæ, Cycladidæ, Cyprinidæ.*

Subdivision 2. *Sinu-Pallialia.* Siphons long, and pallial line indented.

Families. *Veneridæ, Mactridæ, Tallinidæ, Solenidæ, Myacidæ, Anatinidæ, Gastrochænidæ,* and *Pholadidæ.*

CHAPTER XVII.

SUB-KINGDOM: MOLLUSCA—CLASSES: GASTEROPODA, PTEROPODA.

Class II. GASTEROPODA (γαστήρ, belly; ποῦς, foot). This, the first-class of encephalous Mollusca, possesses, like all the rest, a peculiar dentary organ, the *odontophore*. The odontophore is a strap-like organ, studded with three or more closely set rows of 'lingual' teeth, formed of silica; the entire strap plays over a cartilaginous cushion or pulley, which is connected with the lower jaw; the backward and forward movements of the odontophore are effected by distinct muscles. The teeth are constantly renewed by fresh growths from the membrane beneath. The gullet leads to a capacious stomach, which is often supplied with calcareous plates, for the purpose of triturating the food. The intestine, which takes a *hæmal* flexure in Branchio-gasteropoda, and a *neural* flexure in Pulmo-gasteropoda, always terminates in an anus. The liver is large, and salivary glands are always present. Most Gasteropoda move by means of a powerful 'foot;' in some, however, this structure is modified into a fin. The foot sometimes consists of three distinct portions—a *propodium*, anterior portion for swimming; a *mesapodium*, middle portion with a sucker attached; and a *metapodium*: occasionally the *metapodium*, which is farthest from the body, secretes a calcareous lid or operculum, which closes the orifice of the shell.

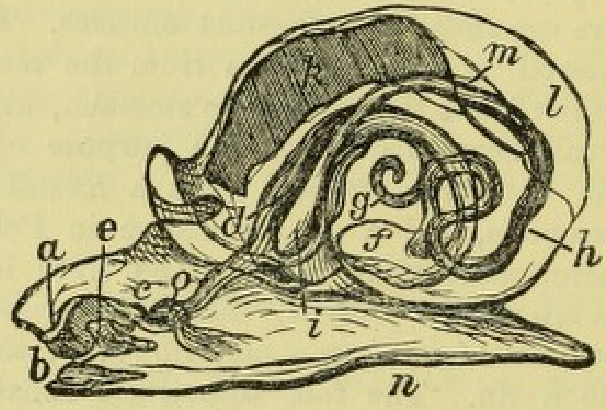
The shell of Gasteropoda is generally univalve, rarely multivalve; when the latter condition is met with, the shell is formed of eight transverse imbricated plates, implanted in the edge of the mantle, the spaces between the plates being often beset with bristles.

The univalve shell is generally a coiled tube, wound round a central axis or *columella*; the nucleus, or earliest part of the shell being at the apex, and the portion last formed being the open mouth at the lower part or base. The direction of the coil may be concentric, but more frequently it is a true spiral.

The heart of Gasteropoda is bicœlian, and a capillary system intervenes between the arteries and veins; but the liver does not possess a distinct portal system as it always does in Vertebrates. Gasteropoda are divided into two large sub-classes—*Branchio-gasteropoda,* Mollusca, in whom the respiration is aquatic, and *Pulmo-gasteropoda,* Mollusca with organs fashioned for aërial respiration.

Sub-class 1. BRANCHIO-GASTEROPODA. The purification of the blood in these aquatic animals is effected in one of three ways—1. By a process of osmosis, the blood coming in contact with the oxygen mechanically mixed with the water, the exchange taking place through the medium of the mantle walls, *e.g.* the *Heteropoda*; 2, by tufted naked branchiæ projecting externally, the *Nudibranchiata*; and 3, by branchiæ enclosed in gill-covers formed by the mouth, the *Siphonostomata*; the water, in the latter group, is admitted through a tubular prolongation of the mouth, or a *siphon* at one end, and discharged through a similar tube at the other. In all

Fig. 37.



MORPHOLOGY OF GASTEROPODA.

Helix communis. *a.* Tooth. *b.* Mouth. *c.* Gullet. *d.* Crop. *e.* Odontophore. *f.* Stomach. *g.* Coiled termination of visceral mass. *k.* Lung. *l.* Renal sac. *m.* Heart. *n.* Foot.

the Branchio-gasteropoda the intestine takes a hæmal flexure. The following Orders are comprised in this Sub-class.

Order 1. **Prosobranchiata** (πρόσω, in advance of; βραγχία, gills). Whelks, Limpets, Periwinkles, Cowries, Tooth-shells, Ear-shells, &c., &c. Diœcious Molluscs, with branchiæ of a plume-like, or pectinated character, situated in a fold of the mantle, which arches over the head. In this vault are also placed the apertures of the mouth and anus. The entire animal can be drawn into the shell by retractor muscles.

Pectinibranchiata. Whelk. The branchiæ are pectinated. Marine carnivorous Gasteropoda, with the mouth produced into a tube or siphon.

Scutibranchiata. Haliotis, &c. The branchiæ are plume-like, and the shell is notched for the passage of the anal siphon.

Cyclobranchiata. Limpets, Chiton, &c. Phytophagous Molluscs. The branchiæ are arranged in a circle between foot and mantle. Shell either univalve, or, as in Chiton, multivalve.

Tubulibranchiata. Periwinkles. Phytophagous Molluscs. Branchiæ are fleshy. The shell is tubular.

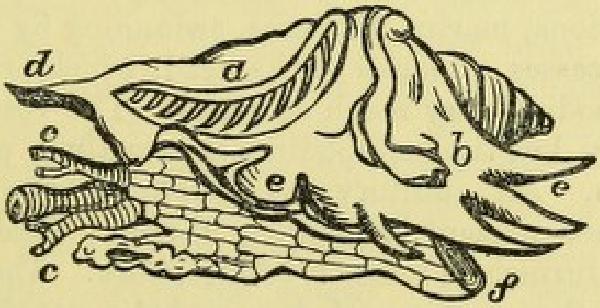
Order 2. **Opisthobranchiata** (ὄπισθεν, behind; βραγχία, gills). Sea Slugs, Monœcious. Gills arborescent, and more or less exposed; situated towards the hinder part of the body. The shell is often wanting.

Tectibranchiata. Marine Gasteropoda, with branchiæ more or less protected by shell or mantle. Includes bubble shells, and sea hares.

Inferobranchiata. Marine Gasteropoda, with branchiæ below the fold of mantle. Example, Pleurobranchus.

Nudibranchiata. Marine Gasteropoda, with branchiæ entirely exposed on the back of body. No shell. Include Sea Lemons,

Fig. 38.



Pterocera, one of the Siphonostomata, seen within its shell, as if the shell were transparent. *a.* Branchiæ. *b.* Digestive tube. *c c.* Tentacula carrying eyes, and having the mouth between them. *d* and *e.* Margins of shell. *f.* Hinder part of the body.

and Sea Slugs, often found clinging to stones, or creeping by foot along seaweed.

Order 3. **Heteropoda**, or **Nucleobranchiata**. Marine Gasteropoda, breathing by the general integumental surface, and swimming by means of an elongated vertical ventral fin-like tail, provided with a terminal sucker, by which they can anchor themselves to seaweeds or other foreign bodies. Some are furnished with shells, others again are shell-less; this fact is made the basis of their divisions into *Firolidæ*, in which the shell is small or entirely absent; and *Atlantidæ*, which possess a well-developed operculated shell, into which the animal can completely retire at will. The Heteropoda are diœcious. An auditory sac is present, connected with the cephalic ganglion ; the intestine is bent dorsally, and the foot consists of the three portions, pro-, meso-, and meta-podium.

Sub-class 2. PULMONO-GASTEROPODA. Land Snails and Pond Snails. Air-breathing monœcious Gasteropoda, with a *neurally* bent intestine. Some have shells, others are unprotected. They are divided into Operculata and Inoperculata.

Order 1. **Operculata**. Air-breathing Gasteropoda, with a shell whose aperture can be closed by a lid or operculum, which is connected with the foot. In some of the Operculata, *e.g.* *Cyclostoma* and *Pupina*, the shell and operculum are both spiral, while in others, *e.g.* *Acicula*, the shell is elongated, and the operculum subspiral.

Order 2. **Inoperculata**. Air-breathing Gasteropoda, without an operculum to close the shell. In some of the Inoperculata, *e.g.* the *Helicidæ* (land snails), the shell is capable of containing the entire animal ; in others, *e.g.* *Limacidæ* (slugs), the shell is rudimentary, and is partially concealed by the mantle, and in others, *Oncidiadæ* (pond snails), there is no shell at all.

Class III. PTEROPODA (πτερόν, wing ; πούς, foot). Very small, monœcious, marine Mollusca, swimming by means of two wing-like processes attached to the head, which are elements of the foot (epipodia), very much enlarged. The rest of the foot is rudimentary, but the metapodium is sometimes provided with an operculum. An auditory sac is connected with the foot. Shell sometimes present, sometimes absent. Head very small, but mouth is furnished with an odontophore. There is a peculiarity about the position of the cephalic ganglion, it being *infra-* instead of *supra*-œsophageal ; it is the only ganglion detectable. The intestine takes a *neural* flexure. These small creatures swim near the surface of the Arctic seas in vast shoals, forming the chief food of the whalebone whales ; they are themselves carnivorous, living on still smaller animals than themselves. Divided into Thecosomata and Gymnosomata.

Order 1. **Thecosomata** (θήκη, sheaths ; σῶμα, body). Head indistinct ; shell external. Examples, *Hyalea*, *Cleodora*.

Order 2. **Gymnosomata** (γυμνός, naked ; σῶμα, body). Head distinct ; shell absent. Examples, *Clio*, *Pneumodermon*.

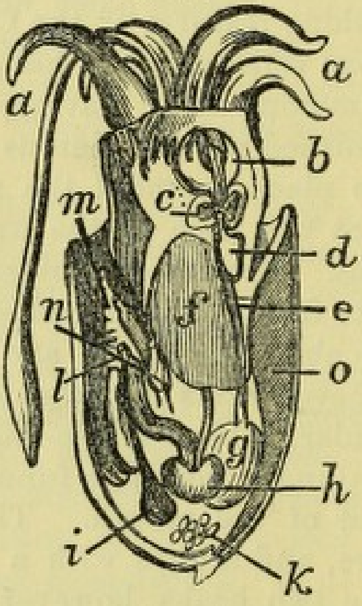
CHAPTER XVIII.

Sub-kingdom: Mollusca—Class: Cephalopoda—Physiology of Mollusca.

Class IV. CEPHALOPODA (κεφαλή, head; πούς, foot). Aquatic, free-swimming, or creeping Mollusca, enclosed in a muscular mantle, and, if a shell exists, in a univalve shell. The chief distinguishing features of the Cephalopoda consist in peculiar modifications which the foot has undergone: this organ is divided into numerous long, waving, but strong tentacles, each, as a rule, furnished with numerous suckers, or *acetabula*; these tentacles are placed around the mouth, which is in a central depression at the base of the wavy feet, which much more resemble arms. Besides the other pedal elements, the *epipodia* are separate from the rest, and enormously developed; they are prolonged above the head and rest of the foot, and unite posteriorly; beyond this they divide again, and are either modelled into muscular, flattened, disc-like oars or into a funnel-shaped tube, the *Infundibulum*, this funnel being always placed at the anterior fold of the mouth. The mouth is supplied with an odontophore, and always with a horny beak, very like a parrot's bill; the two beaks, however, move on an antero-posterior plane, and not vertically, as is the case with birds. The intestine performs a *neural* flexure. They respire by branchiæ, which are either two or four in number. The integument contains pigment sacs, called *cromatophores*, which sometimes tint the weird animal with bright and variegated colours. Many Cephalopoda, although destitute of an external shell, possess an internal shell or rudimentary skeleton, which varies in perfection. This is known as the 'sepiostaire,' 'cuttle-bone,' or 'pen.' In the Loligo or common calamary the 'shell' consists of an 'elongated, pen-like structure, composed of horny material, perfectly transparent and flexible, being contained in the centre of the dorsal portion of the mantle. In the Sepia, however, the shell is in a much higher state of perfection, consisting of an oval plate of calcareous matter, which evinces at its broader and concave end a tendency to further development, and approaching somewhat to the condition of the shell of the extinct Belemnite.

The head, or *prosoma*, is clearly defined, and separated from the body by a neck; it bears a pair of prominent, large, globular eyes, and is, as a rule, surrounded by the wavy arms. The head rises out of the shell, but the body, or *metasoma*, remains concealed; many, however, of the Cephalopoda are entirely naked, *i.e.* have no shell. Each of the suckers is surrounded by a strong set of radiating muscular fibres, which in contracting (when the surface of the sucker is applied to any object) produces a vacuum beneath, and so enables the animal to form a firm anchorage; and, if the object seized be a living creature, to exhaust its victim by the continuous cupping action of the acetabula.

Fig. 39.



MORPHOLOGY OF CEPHALOPODA.

Sepia officinalis, laid open to show viscera, &c. *a*. Foot. *b*. Horny jaws. *c*. Principal ganglion. *d*. Salivary gland. *e*. Œsophagus. *f*. Liver. *g*. Stomach. *h*. Pyloric cæcum. *i*. Ink bag. *k* Ovary. *l*. Aperture of atrial system. *m*. Branchiæ. *n*. Oviduct. *o*. Cuttle-bone.

The powerful mouth leads to a gullet, this to a stomach, and the intestine after bending *neurally* terminates ventrally near the base of the funnel. Salivary glands, a pancreas, and a large liver pour their secretions into the intestine.

In addition to these viscera a large secreting sac, the *ink-bag*, is often present, containing a dark-coloured fluid, which the animal ejects at will through a duct situated, like the anus, at the base of the funnel. This is provided to render the animal's escape from pursuit more secure; those Cephalopoda, such as the Pearly Nautilus, which are sufficiently protected by a shell, do not possess an ink-bag.

Respiration.—Two or four pairs of plume-like branchiæ are situated within the pallial cavity, into which the sea-water is admitted at one end, and expelled, through the funnel, at the other by muscular contraction. The contractions occurring rhythmically, subserve the double purpose of keeping up a current of fresh water, and of assisting in locomotion; the succussion caused by the expelled water driving the animal in an opposite direction.

Circulation.—A large tricœlian systemic heart is present, which pumps the blood all over the body; it then passes through capillaries into veins which conduct the blood back to the gills, where it is purified, and whence it is propelled to the heart by contractile sacs called branchial hearts, placed at the base of each gill.

Nervous System.—Cephalic, parieto-splanchnic, and pedal ganglia all present, but the cephalic is much the largest, and is often protected by a plate of cartilage, which may be regarded as a rudimentary cranium.

Reproduction.—The sexes are always distinct. Testes contain spermatozoa, which are agglutinated within the 'spermatophore.' During reproduction the spermatozoa are temporarily transferred to one of the arms, which becomes curiously altered and unfit for locomotion; in this condition it is said to be *hectocotylised.* The hectocotylised arm of a male Cephalopod is then applied to the ovary of a female, sometimes becoming completely detached, and placed within the pallial cavity of the female, at other times it remains attached to its original owner, and simply transfers its contained spermatozoa to the ovary.

As already intimated, the shells of Cephalopoda are sometimes external, sometimes internal, and occasionally wanting. When the shell is internal it is variously shaped, like a pen, the *gladius*, as in the Loligo, or resembling a spoon as in the Sepia; at other times it is coiled and many-chambered, when it is termed a *phragmacone.* The phragmacone, which is a true internal skeleton, must be distinguished from the shell of the Nautilus, which is external.

The *Argonaut* and the *Nautilus* are the only surviving Cephalopoda with external shells, but they were very numerous under the name of Ammonites in the Mesozoic strata, especially in the Cretaceous series. Although the Argonaut and Nautilus both possess external shells, they differ widely from each other in many important points. In the *Argonaut* (the Paper Nautilus), the shell is unilocular, and serves as a receptacle for the ova of the female ; it is therefore 'a nidamental shell :' it also receives the hectocotylised arm of the male. The male is an Octopus pure and simple. There is no vital connection between the Argonaut and its shell.

In the *Pearly Nautilus*, on the other hand, the shell is a true pallial secretion, and is many-chambered ; it is a beautiful concentrically coiled shell, with chambers separated from each other by transverse walls or septa, but with a tube running through the centre of each, following the curves of the shell, and establishing a communication between the last chamber, in which the animal dwells, and the apical one, the first formed. This tube is called the *siphuncle*, and enables the animal to sink or swim at pleasure by alternately filling the tube with water, and then expelling it by muscular contraction.

Cephalopoda contain two orders, *Dibranchiata*, Cuttle Fish, Squids, Loligo, Paper Nautilus, &c., and *Tetrabranchiata*, of which the Pearly Nautilus is the only living form, but of which there are many extinct families.

Order 1. **Dibranchiata.** Cephalopoda with two branchiæ, each of which is furnished with a branchial heart. Ink-bag always present. They are generally naked, but have an internal skeleton ; or if the skeleton be external, it is unilocular. Funnel complete ; arms, eight or ten, provided with suckers.

The *Poulpes* (*Octopodæ*) are formidable creatures, with eight powerful tentaculated arms. They swim vigorously, by the repeated and forcible ejection of water from the funnel, and are extremely rapacious. Included in this class is the Argonaut.

The *Argonaut* is a squat-shaped animal, that sits in its single-chambered shell with the funnel turned towards the keel, and the webbed dorsal arms generally applied against the sides of the shell ; they can, however, be raised above the creature's head, when they assist it in sailing. The suckers upon the eight arms are sessile. This description applies to the female alone, the minute male not being protected by a shell at all.

Decapoda, or ten-armed Dibranchiate Cephalopoda, comprise the *Calamaries*, *Cuttle Fish*, *Spirulidæ*, and the extinct *Belemnites*.

Two of the arms are always longer than the rest, having expanded extremities, armed with suckers or sharp hooks. Suckers pedunculated. An internal skeleton is present, and there are lateral fins. In the *Calamaries*, or *Squids*, the skeleton, called the *gladius*, is formed of a central shaft and two lateral pieces, the whole being lodged in the mantle.

The *Belemnites* appeared for the first time, and in great numbers, in the seas of the Liassic period. Of this Cephalopod we only possess the fossilised 'bone.' This little slender bone, the only vestige remaining to us, was merely the terminal portion surrounded by the flesh of the body of the animal. The ink-bag of the Belemnite has been found in a fossilised state.

Order 2. **Tetrabranchiata.** Four-gilled Cephalopoda, with a many-chambered, siphunculated, external shell. Funnel incomplete ; no ink-bag. The Tetrabranchiata creep head downwards along the bottom of the sea.

The Pearly Nautilus, which is the sole surviving representative of this once numerous order, is a soft-structured mollusc, inhabiting a beautifully involuted shell. As the animal grows larger it creeps further and further along the shell, which is constantly being secreted by the mantle, and having vacated its former chamber for a newer and larger, it shuts off communication with its old home by secreting a nacreous septum, or wall of division ; a central membranous tube, however, ever follows the winding of the shell, and pierces the centre of each partition. The Pearly Nautilus possesses many arms, but there are no suckers. The head can be entirely retracted within the shell.

The shell of the extinct *Ammonite* differs from that of the Pearly Nautilus in the septa being folded and complex, and in the siphuncle running along the convex periphery of the shell.

Physiology of Mollusca.

In briefly reviewing the physiological processes of Mollusca we shall of necessity recapitulate many of the points referred to in describing their morphology.

The high degree of development in the internal organs of Mollusca induced Cuvier to rank them at the top of the Invertebrate scale ; but many of the Annulosa, notably Insecta, in the high development of their nervous system, more truly merit this position. We have to examine into the processes of Digestion, Circulation, Respiration, Locomotion, and the Nervous System.

Digestion.—The first thing that strikes us in the digestive system of Mollusca is the similarity which it bears to that of birds. In both (as a rule) we find a crop, a gizzard, and true digestive stomach, the difference being that in birds, the digestive stomach (the proventriculus) is placed before the gizzard, while in the Mollusca the gizzard is placed before the digestive stomach.

The *Cephalopoda* possess prehensile organs in the tentacles which surround the mouth ; most other Mollusca depend upon ciliary action for the conveyance of their food, others have no prehensile organs but their mouths.

The *Cephalopoda* have parrot-like beaks, which open and shut vertically. All other Mollusca, except Lamellibranchiata, are furnished with an organ which serves the purpose of a masticatory apparatus. This organ, situated in the roof of the mouth, was formerly called a tongue, but now is known as the odontophore ; it is a strap-like organ, beset with teeth, and worked in a rasping, file-like manner by muscular action.

The buccal cavity in all Mollusca opens at once into the œsophagus, which dilates often into a crop ; below the crop we find a strong muscular bag, the gizzard, which, in the most perfectly developed Mollusca, the Cephalopoda, is furnished with two lateral digastric muscles ; there is another expansion below the gizzard, which represents the true digestive stomach ; the intestine is long in vegetable-feeders, short in animal-feeders, particularly in the Lamellibranchiata. There is no distinction into large and small intestine.

Cephalopoda, Pteropoda, and Gasteropoda are all furnished about the mouth with a salivary gland.

The liver is very large in all Mollusca. It is solid, lobulated, and has two ducts : a portal *venous* system is never present. In some Cephalopoda and Branchio-gasteropoda an organ resembling a pancreas exists.

Circulation.—The heart of Mollusca is either single or double ; it is always systemic in character. In aquatic Mollusca the circulation is carried on as follows :—The blood, like the blood of all Invertebrates, is not coloured with cruorin, but is either colourless, or has a greenish tinge ; it is, however, corpusculated. This blood is propelled by a strong muscular ventricle through tubes to every part of the body, except the gills ; from all these parts it passes, directly and without the intervention of capillaries, into returning channels or veins ; these veins then pass to the gills, and present in the higher forms distinct pulsatile cavities, known as branchial hearts, which propel the blood throughout the gills, where it is purified ; it is then returned by branchio-cardiac veins either directly to the ventricle, as in Pteropoda and Lamellibranchiata generally, or by the intervention of an auricle, as in Gasteropoda and Cephalopoda. The blood is not entirely contained in vessels, but is pumped into lacunæ, or spaces, whence it is re-collected into vessels. In the terrestrial Mollusca the heart is also single and systemic, but the blood, instead of being collected into branchial veins, is collected into vessels which ramify over the pulmonary air-sac, and purify it there ; thence it is returned into an arterial auricle placed above and separated from the right ventricle by a valve.

Respiration.—Most Mollusca are aquatic and respire by branchiæ. In many these are ciliated, *e.g.* Pteropoda, Branchio-gasteropoda, except in some of the lowest, which are supposed to respire by their surface only; in others the gills are non-ciliated, *e.g.* Cephalopoda. The position of the respiratory organs is various.

Some Mollusca (Pulmo-gasteropoda) are terrestrial and respire by air-sacs. The air-sac communicates with the external air by an aperture on the left side of the neck, and is placed within the mouth and the smaller coils of the shell. It is hollow, ciliated, and abundantly supplied with blood.

Nervous system.—The three principal ganglia, cephalic, pedal, and parieto-splanchnic, have each special functions of their own. The *cephalic*, representative of the vertebrate brain, is the centre of all *sensori-motor* actions—it even exercises a weak volitional power over the rest, as seen in the search for food. The other ganglia are brought into connection with it by nerves. All the organs of sense, except that of hearing, receive nerves directly from this ganglion; the organ of hearing is supplied by the pedal ganglion, but is connected by a nervous twig with the cephalic ganglion. The *pedal* ganglia are the centres of the reflex excito-motor actions, and therefore are representatives of the vertebrate spinal cord. The *parieto-splanchnic* ganglia are the centres which preside over organic life, supplying the branchia, the heart, and the digestive system, and may therefore be looked on as representatives of the sympathetic system.

Senses.—Organs of smell, sight, and hearing exist in all Mollusca.

Smell.—In the Cephalopoda the organs of smell are two small cavities, placed near the back of the eye—they each receive a twig from the side of the optic nerve. In the other Mollusca the sense of smell resides in the sensitive tentacula found at the entrance to the mouth.

Sight.—The organs of sight, which are very perfect in Cephalopoda, become gradually simplified as we descend the Molluscous classes. In Cephalopoda the eyes are very large, and connected by optic nerves to the cephalic ganglion. There is no anterior chamber, but with this exception, the tunics and humours resemble those in man; the lens is very dense, and projects into the water. There is a muscular iris and ciliary processes.

All the remaining Odontophora have eyes. In the Pteropoda they are shaped like a bent cylinder. In the Pulmo, and

Branchio-gasteropoda they are numerous black points, each consisting of a transparent elevation of the soft skin of the tentacle, a globular lens, a choroid with an iritic opening, and an optic nerve expanding into retinal elements.

Many *Lamellibranchiata* are eyeless ; in some, however, as *e.g. Pecten*, eye-spots exist, which are situated at the free edge of the mouth, projecting between the valves.

Hearing.—All Molluscous classes possess organs of hearing. They are composed of cavities filled with a gelatinous fluid, and containing cretaceous otoliths ; the sacs are always in close connection with the auditory nerves, which either spring from the subœsophageal cephalic ganglion, as in Cephalopoda, &c., or from the pedal ganglion, as in most of the remaining Mollusca.

CHAPTER XIX.

SUMMARY OF THE COMPARATIVE PHYSIOLOGY OF INVERTEBRATA.

IN this chapter a general summary of the physiological processes of Invertebrata is given, being of the nature of a recapitulation of the preceding chapters.

PREHENSILE ORGANS. **Protozoa.**—The unciliated Protozoa obtain their food by direct imbibition. *Spongida* and *Infusoria* by the currents induced by the vibratile cilia.

Cœlenterata. The non-ciliated oral tentacles of the *Hydrozoa* and *Actinozoa* constitute the sole prehensile organs.

Annuloida. *Scolecida* obtain nutriment by general absorption through the body walls, or by a special suctorial apparatus. *Rotifera* possess a ciliated disc, which creates a current, and so wafts food towards the mouth. *Echinodermata* possess special prehensile organs in the vibracula, the three-pronged pedicillariæ probably also acting in the same way; the long arms of many of the star-fishes are employed in the search for food.

Annulosa. The chelæ, or claws of the *Crustacea*, the haustellate or masticatory mouth of *Insecta*, the tentacles of the lob-worms, and the suctorial toothed mouth of the leeches, are varieties of the prehensile organs of this large sub-kingdom.

Molluscoida obtain nourishment by the movement of ciliated oral tentacles.

Mollusca. Food is conveyed to the mouth by cilia in some, or directly seized by the unciliated mouth, or, as in the Cephalopoda, is grasped by the suckers attached to the waving arms or feet.

TEETH.—Neither **Protozoa** nor **Cœlenterata** possess teeth, but *Nassula*, and some other Ciliate Infusoria, possess an internal cylinder of parallel rods for the mastication of their food.

Annuloida. *Scolecida* have no denticles, but *Rotifera* and *Echinodermata* both possess complex teeth; in Rotifera the denticles are in the shape of denticulated plates, placed transversely to the mouth, and in Echinodermata the teeth, five in number, are very large, and constitute the formidable masticatory apparatus known as the 'lantern of Aristotle.'

Annulosa. The leech possesses three semilunar serrated teeth, implanted in the muscular walls of the mouth; the remaining classes possess no teeth, but their mandibles and maxillæ are often very dense and chitinous, and form efficient cutting organs ; the different pieces are always worked transversely.

Molluscoida have no teeth.

Amongst **Mollusca**, the *Gasteropods* possess a strap-like organ, called the odontophore, which is studded with rows of teeth, and worked backwards and forwards by powerful muscles. *Cephalopoda* possess horny jaws, which move vertically. Denticles are also situated in the mouth of the other Molluscous classes.

SALIVARY GLANDS.—Neither **Protozoa** nor **Cœlenterata** possess such organs.

Annuloida. *Echinodermata* are furnished with cæcal tubes, which surround the gullet, and secrete a viscid fluid for mixing with the food, and they therefore may be regarded as salivary glands ; similar organs are said to exist in the *Rotifera.*

Annulosa. The *Cirrhopoda* possess large cement glands, which are homologous to the salivary glands, and other Annulosa possess these organs in the shape of tubes more or less branched, and opening into some part of the alimentary tract between the mouth and stomach.

Molluscoida do not possess salivary glands.

Mollusca all possess salivary glands, placed near the mouth, and often of considerable size.

STOMACH AND INTESTINES.—**Protozoa**. No trace of an alimentary canal is found in *Gregarinida*, *Rhizopoda*, or *Spongida*, the first instance of its appearance being in the *Infusoria*, where we find a large depression or mouth leading to a short cæcal tube, called the gullet.

Cœlenterata. All possess a mouth and a stomach, but are not provided with an anal opening, the undigested portions being ejected by the oral aperture. In the compound Cœlenterates there is a community of stomach, but individuality of mouths. In the *Actinozoa* the wide stomach is suspended by mesenteries within the body cavity ; in the *Hydrozoa* there is no perivisceral space, the stomach, as it were, being excavated out of the body sarcode.

Annuloida. *Scolecida*. The Tæniada and Acanthocephala have no alimentary canal, and live by osmosis of the surface. The Trematoda have a single, or double, or branched tube, which is not terminated by an anal outlet. The Nematoidea possess a complete canal, with both mouth and anus. The Turbellaria possess a simple, or branched, or sacculated, aproctous tube. The *Rotifera* possess a mouth, a crop, a gullet, a stomach, and an intestine, which terminates anally on the dorsal surface.

The *Echinodermata* are furnished with a well-developed alimentary canal, which terminates in an anal outlet, placed on the opposite pole to the oral aperture ; in the radiated forms a diverticulum from the stomach passes into each ray, and in the Echinidea the gut which succeeds to the stomach performs two curves round the shell before terminating in the anus.

Annulosa. The Annelida are furnished with a straight digestive tube, having a mouth at one end and an anus at the other ; it is often branched, or regularly sacculated. The Earthworms possess a curious cæcal tube in their intestine, the use of which is unknown, and which is called the *typhlosole. Myriapoda* possess a very similar alimentary canal to the former, it being straight and simple in the carnivorous varieties, straight and sacculated with cæcal diverticula in the vegetable-feeders. *Crustacea*, at least the higher forms, are supplied with a gullet which conducts to a stomach or gizzard, in the walls of which are situated numerous and regularly arranged denticles, which masticate the food at the same time that the gastric juice is digesting it ; the resulting intestine is generally short and is sometimes supplied with two cæca. The gastric denticles are shed and renewed every time the animal casts its shell. The *Arachnida*, being carnivorous, have short and simple digestive tubes ; the stomach often has four cæcal diverticula appended to it. *Insecta.* The alimentary canal of Insecta changes during their metamorphosis—in the larval form the canal is straight, with a slight dilatation for the stomach, and a second higher up for the crop ; the intestine, too, is often furnished with two cæca. In the imago the mandipulate apparatus conducts to a glandular crop, this to a gullet, which leads to a gizzard ; the gizzard, unlike the same organ in Birds, is placed above the true digestive stomach ; the latter is a thin muscular dilatation, furnished with numerous gastric follicles and glands, while the former, the gizzard, is a very strong muscular apparatus, often supplied with denticles, which perform a second masticatory operation. The intestine is thin, often provided with cæca, and ends in a cloaca.

Molluscoida. *Polyzoa.* The tentaculated mouth leads to a wide 'pharynx,' to which succeeds a stomach and intestine; the latter bends upward, and terminates near the mouth, where it commenced. *Ascidioida* and *Brachiopoda* also possess a complete but narrow alimentary canal, the anus being placed near the oral aperture. In Ascidians the intestine makes a *dorsal* turn, in Brachiopoda and Polyzoa a *ventral* flexure.

Mollusca. *Lamellibranchiata* possess a transverse mouth, a gullet, a comparatively thin stomach, and an intestine, which after a few coils ends on the hinder part of the mantle. *Gasteropoda* have an alimentary canal like insects, presenting for examination a crop, a gullet, a gizzard, with denticles, a true digestive stomach, or *postventriculus*, and an intestine, which bends upwards and ends on the forepart of the body. *Pteropoda* have similar alimentary canals. *Cephalopoda.* The gullet pierces the cephalic cartilage, and ends in a strong gizzard, which is furnished with two digastric muscles ; to the gizzard succeeds another large dilatation, with a freely secreting mucous membrane, and which is probably a true digestive stomach ; beyond this again the intestine, after a few convolutions, bends up and terminates in the branchial chamber near the mouth.

THE DIGESTIVE GLANDS.—**Protozoa** do not possess any organs homologous to the liver or pancreas.

Cœlenterata do not possess a liver or pancreas, but a mass of gland-cells sometimes exists in connection with the intestine, which is probably homologous to the former organ.

Annuloida. The simplest form of liver is presented by the single long follicle, which opens into the intestine in Trematoda ; the remaining Scolecida do not possess any such organ. *Echinodermata* occasionally possess some secreting cells in connection with the intestine, which secrete a coloured fluid like bile. Rotifera also possess a rudimentary liver. There is no pancreas among the Annuloida.

Annulosa. The *Annelida* possess hepatic follicles. The *Myriapoda* are furnished with numerous hepatic tubuli, which open below the stomach. *Insecta* and *Arachnida* also possess tubular secreting hepatic organs, which are sometimes very numerous, as in Dytiscus, at others very few, as in Gryllus. *Crustacea* possess a large, often yellow, glandular liver, divided into lobes and lobules ; the follicles within being much ramified.

Molluscoida. *Polyzoa* possess small hepatic tubules. *Ascidioida* are furnished with a small glandular liver, while in *Brachiopoda* it is large and minutely lobulated.

Mollusca. The liver is a very large and lobulated gland in all the Mollusca, generally furnished with two excretory ducts. The mollusca alone among Invertebrata possess, in some tubular appendages near the liver, an organ which is homologous to the Vertebrate pancreas.

ORGANS OF CIRCULATION.—**Protozoa.** No organs of circulation exist in the Protozoa.

Cœlenterata. No separate organs of circulation exist, but the gonocalycine canals in many, which radiate from the stomach, serve to keep up a change in the nutritive fluids which go to distant parts of the organism. The fluid which these canals contain, although nutritious, is not corpusculated or true blood.

Annuloida. None possess a true circulatory apparatus, but all possess a *water-vascular* system, which is probably contrived to answer the double purpose of respiration and circulation. These water-vessels are little ciliated tubes, which communicate at some point with the exterior. In the *Scolecida* the water vessels form a sort of ladder. The vessels running down each side of the proglottis join a transverse branch at the posterior part. The ambulacral vessels of *Echinodermata* chiefly subserve a locomotive purpose.

Annulosa. In the *Annelida* there is no distinct heart or blood-vessels, but there is a fluid containing oat-shaped corpuscles, which is circulated throughout the body of the worm or leech, by ciliary action and the movements of the body. The fluid is contained in perivisceral spaces, but not in vascular tubes. In addition to this, Annelida possess a more corpusculated fluid, which is contained within freely ramified tubes, with contractile spaces on hearts placed at intervals. This is the *pseudohæmal* system, and is connected with respiration; the fluid flows along the dorsal aspect towards the head, and along the ventral aspect towards the tail. The movement in the pseudohæmal system is maintained by the above-mentioned contractile hearts and by the presence of cilia. When we reach the *Arthropoda* we meet for the first time with a distinct circulatory apparatus. The typical arrangement is the following: there is a dorsal contractile and segmented vessel, which propels the blood towards the head; after feeding the entire body, this blood is exposed for purification to the oxygen of the air or water, and after undergoing that process is returned to the heart. The chief modifications are the greater or smaller number of valved segments in the dorsal vessel, and the presence or absence of returning veins. The valved segments more or less correspond to the number of body segments: thus they are numerous in *Myriapoda*, fewer in *Insecta* and *Arachnida*, and fewest of all (indeed, there is only one contractile cavity often) in the *Crustacea.* In the latter class there is a dorsal heart, *e.g.* in the lobster, consisting of a single ventricle, placed beneath a venous sinus, which pumps the blood all over the body, returning through lacunæ, but not through capillaries; it is then conveyed to the gills for purification, and is finally returned to the heart by the branchio-cardiac veins. The ventricle gives off five or six systemic arteries, which are called from their destination, ophthalmic, hepatic, antennary, and ventral or sternal arteries.

The Scorpion is the only annulose animal with a distinct ventral vein.

Molluscoida. The *Ascidioida* possess an unvalved heart, which first pumps the blood one way and then another. In the compound *Ascidioida* this aberrant style of circulation is carried on through the stolon or common foot-stalk. *Brachiopoda* possess a valved heart, which is systemic in action. *Polyzoa* have no circulatory organs whatever, but obtain their nutritious fluid like Cœlenterata by osmosis through the diaphanous body wall.

Mollusca. *Lamellibranchiata* have a trilocular heart, composed of two auricles and one ventricle, contained in a large venous sinus. The blood passes from the arteries into lacunæ, or spaces, and before returning to the heart is transmitted for oxidation to the gills. *Gasteropoda* as a rule have a bilocular heart, consisting of one auricle and one ventricle ; the branches of the aorta pass to lacunæ in the perivisceral cavity before going to the gills or air-sacs, according to the aquatic or terrestrial habits of the particular Gasteropod. *Pteropoda* possess circulatory organs similar to Gasteropoda. *Cephalopoda* are furnished with a powerful muscular heart, situated in the middle of the body, which is trilocular in character. Two aortæ, one going to the head, and the other distributing blood to the rest of the body, pass from the single ventricle ; the arteries terminate in capillaries, their only appearance in the Invertebrate kingdom, and through them the blood goes to the two or four gills as the case may be, whence it is propelled by branchial hearts to the two auricles. As there are no lymphatic vessels in Invertebrata, the vascular system of the latter must be regarded as representing both the hæmal and the lymphatic system of Vertebrata. The Invertebrata, though frequently possessing hepatic arteries, which are given off directly from the aorta, never possess a portal venous system, nor is the blood, although corpusculated, ever red, but is generally colourless, or green in colour. The corpuscles again are generally granular in outline, though sometimes they are smooth and discoid, or perhaps angular.

RESPIRATION.—**Protozoa** cannot be said to possess any definite and distinct organs of respiration, but yet are furnished with certain arrangements as a rule, by which the process is carried on.

Bathybius is believed by some naturalists to possess the power of obtaining nourishment directly from the simple chemical elements, after the fashion of plants. *Gregarinida* and *Rhizopoda* probably directly absorb oxygen through their delicate body walls. *Infusoria* keep up a superficial current by ciliary action, and the almost rhythmical contraction of their contractile spaces. *Spongida* also maintain a continuous afferent and efferent flow of oxygenated water through the pores and oscula by means of their ciliary lining.

Cœlenterata. The gonocalycine canals probably subserve a respiratory purpose in those Cœlenterates who possess them ; in others, oxygen is directly absorbed into the tissues by the law of dialysis.

Annuloida. *Scolecida* probably respire by means of the water vessels, and directly through their skin. *Rotifera* are mainly dependent upon the ciliated trochal disc for bringing them fresh oxygen. *Echinodermata* respire by their water and ambulacral vessels. The Holothuridea possess a very beautiful much-branched tube, called the *respiratory tree*, which is situated within the body of the animal, projecting into the perivisceral space, and communicating with the common cloaca.

Annulosa. Some *Annulosa* are aquatic, others are aërial in respiration. *Aquatic Annulosa* breathe by branchiæ or gills ; these organs are generally placed externally in Annelida, being around the head, as in *Serpula*, or on the back, as in *Nereis* ; sometimes they are internal, as in *Polynæ*. The *Crustacea*, except the very lowest, such as the Pycogonida, which have no differentiated respiratory organs, and the aquatic Arachnida, respire by branchiæ situated in a branchial chamber. The lobster, *e.g.*, has twenty-two flattened branchiæ on either side, to which water is freely admitted by the continual flapping of the gill covers, and by the baling process of the scaphognathite. In none of these Annulosa are the gills ciliated. *Aërial Annulosa*. The air-breathing *Annelida*, such as the earthworm and the leech, respire by means of little sacculi, which open externally by small ducts on each segment of the body. *Myriapoda* possess a series of tubes, kept constantly patent by an internal elastic thread, which communicate with the exterior, and which are connected together by cross branches ; the little apertures by which they communicate with the air are called *spiracles*, or *stigmata*.

Arachnida possess air-sacs often plicated, and communicating like the tubes in Myriapoda with the exterior by means of stigmata. The water spiders are aërial in respiration, carrying down the necessary oxygen to their dwelling-places after continuous journeys to the surface.

Insecta possess what is called a *tracheal* respiration : the tracheæ being small and freely communicating tubes, which are kept patent by a coiled elastic thread, as in Myriapoda, only much more perfectly. The tracheæ pass to the external air by stigmata, and ramify through every part of the body, sometimes even piercing the insect's compound eye; the wings of insects are chiefly tracheal expansions, and may therefore be regarded as associated with the respiratory function, though not so much as with the power of flight: thus, if the wings of an insect be cut off, they do not speedily die asphyxiated. The larvæ and pupæ of Insecta likewise possess and breathe by tracheæ.

Molluscoida. *Ascidioida* possess a large respiratory sac, or *atrium*, through which water is being constantly passed by ciliary action. *Brachiopoda* breathe by vesicular inflections of the mantle. *Polyzoa* maintain a current through their hollow tentacles and the perivisceral cavity by ciliæ, which are placed around the mouth.

Mollusca. *Lamellibranchiata* respire by two pairs of flat or lamellar gills, which are beautifully ciliated, and afford one of the best and most accessible illustrations to the microscopist of ciliary motion. When the shell is closed, the water is admitted at one side and expelled at the other; when the shell, however, is open, the branchiæ float free in the water. *Branchiogasteropoda* sometimes respire directly by the skin, as *e.g.* in some Nudibranchiata, but generally by fringed gills, which are placed in the last coil of the univalve shell, and to which the water is admitted by a tube or by a large patent mantle. *Pteropoda* breathe by laminar gills, placed either inside or outside the mantle. *Cephalopoda* possess one or two pairs of large branchiæ, which are never ciliated, and are placed within the mantle, receiving water at one end of the tube or syphon, and expelling it at the other by alternate contractions of the mantle and of the tube itself. The *Pulmogasteropoda* alone among Mullusca respire air; in them a large sac is placed beneath the shell, and communicates with the air by a slit on the left side of the neck. The sac is lined with cilia, and freely supplied with blood-vessels.

NERVOUS SYSTEM.—**Protozoa.** In none of the Protozoa has a nervous system ever been demonstrated.

Cœlenterata. In a few instances a minute ganglion has been seen, which sends off twigs to the body sarcode, and to the so-called lithocysts.

Annuloida. *Scolecida* and *Rotifera* possess a single, double, or quadruple ganglion, which sends off efferent and receives afferent twigs. *Echinodermata* have a narrow collar, with five ganglia upon it, *e.g.*, one for each segment, which sends twigs to the eye-spots, ear sacs, and every part of the creature's body.

Annulosa possess a supra-œsophageal or cephalic ganglion, a nervous collar embracing the œsophagus, an infra-œsophageal ganglion, and a double gangliated ventral cord, which transmits filaments to every part of the body. The nervous system of Annulosa often possesses, in addition to the sensori-motor and excito-motor functions, which have been the sole functions of the preceding sub-kingdoms, a certain ideational or volitional power. The nervous system of Annulosa is much more concentrated in those members of the group which have the segments much welded together, as Arachnida and Crustacea, than in those possessing many serially similar segments, such as the Myriapoda.

Molluscoida are furnished with a single ganglion, placed near the mouth, and sending twigs to the tentacles, the eye-spots, and the body-walls. It is reflex in function.

Mollusca. The typical arrangement of the nervous system in Mollusca is not unlike that of Annulosa, viz., there is a cephalic, a pedal, and a parieto-splanchnic ganglion, which are connected by commissural fibres. The cephalic ganglion represents the supra- and sub-œsophageal ganglia of Annulosa, and transmits nerves to all the organs of sense and all the parts about the head. The pedal ganglion, placed in the 'foot,' is generally single, but sometimes, as *e.g.* in the Cephalopoda, is much divided; it supplies the greater part of the locomotive organs. The parieto-splanchnic ganglia supply the viscera of organic life, and, consequently, preside over the respiratory, circulatory, and digestive apparatus. The functions of the nervous system of Mollusca comprise slight powers of volition, as well as the usual reflex functions, such as excito- and sensori-motor powers.

THE ORGANS OF SENSE. **Protozoa** possess none, with the exception of a few Infusoria, which are said to be furnished with eye-spots, but unless these are connected with a nervous system, which as yet has not been determined, it is clear that these spots are not sentient ocular organs, but merely small masses of pigment.

Cœlenterata. *Sight.* The Medusæ are provided with pigment spots and a lens-like body, situated in the borders of the disc, in contiguity with the lithocysts, and in connection with a nervous ganglion. Other Cœlenterata possess eye-spots alone, without any lens.

Hearing. Most Cœlenterata, but particularly Medusæ, possess numerous *lithocysts*, little sacs with calcareous particles, situated round the border of the disc.

Touch. The thread cells are not organs of touch so much as destructive weapons of offence.

Smell does not exist.

Annuloida. *Sight.* Echinodermata, a few Scolecida, and all the Rotifera are supplied with eye-spots, which are placed near the principal ganglion.

Hearing. Nearly all Annuloida are destitute of organs of hearing ; but a few Rotifera, and the Turbellariæ among Scolecida possess a single auditory sac, near the principal nervous ganglion.

Smell, Taste, and Touch. Annuloida are probably entirely destitute of organs of smell, taste, and touch.

Annulosa. *Sight.* All Annulosa possess eyes, which are, however, of very different degrees of perfection. *Annelida* are furnished with ocelli alone, which are probably only capable of affording the animal a sense of light and darkness, without enabling it to distinguish objects. The construction of the ocelli is simple enough ; an expansion of nervous substance behind a coat of pigment, which in its turn is covered by a transparent membrane formed from the cuticle, constitutes an ocellus. To this a lens is sometimes added, as in the Leech and Nereïs. The Leech has ten of these eyes, the Nereïs and Eunice have each four. *Myriapoda.* Some are blind, but most possess simple eyes, aggregated together to form the conglomerate eye ; others possess true compound eyes, like insects. The simple eye is an advance in complexity upon the ocellus, there being a pupillary opening in the choroid or pigmentary coat, a cornea, and a lens, as well as a nervous expansion or retina. The eyes of Myriapoda vary in number from four to forty. *Crustacea.* Some few low and aberrant forms, such as the Cirrhopoda, are eyeless ; all the others possess eyes, generally compound and stalked, sometimes simple and sessile. The formation of the compound eye has been described at page 70. The peduncle, or stalk, enables the Crustacean to turn his eye in any direction, even to look completely behind him if need be. The eyes of Crustacea, as a rule, do not exceed two or three in number. *Arachnida.* The lower forms are eyeless, but the great majority possess well-developed and singularly bright simple eyes, from two, in the Mites, to ten, in the Scorpions. *Insecta* are supplied with both simple and compound eyes ; the number of separate corneal facets in the latter, each being connected with a twig of optic nerve, is extraordinarily numerous ; *e.g.* the common house-fly is said to have 8,000, the dragon-fly 12,000, and the Mordella beetle 25,000 of these single eyes, which are united in the two compound eyes. As neither the optic nerves, or columns of the nervous cord decussate, the image seen by each eye is probably received by the nervous ganglion of the same side, and not reversed, and then corrected, as in the eyes of Vertebrata.

Hearing. Most of the Annulosa possess acoustic organs. *Annelida* have two auditory sacs in connection with the nervous collar, which surrounds the œsophagus. *Myriapoda* are stated not to possess any organ of hearing. *Crustacea* possess auditory sacs, with contained otoliths, or otoconia, placed at the base of the first pair of antennæ. These sacs are in communication with the subœsophageal nervous ganglion. *Arachnida* have not been shown to possess an auditory apparatus. *Insecta* possess auditory sacs, generally filled with fluid, and containing calcareous particles, which are variously situated; *e.g.* in the Grasshopper these organs are placed in the abdomen, on either side of the first abdominal ring; in Flies, and most insects indeed, the ears are placed at the base of the antennæ, and in some Locusts upon the chief segment of the first pair of legs; thus some have legs, others bodies, and others again antennæ, which can hear.

Smell. It is thought by some, that the same organs which have been mentioned above as acoustic organs may serve equally for organs of smell; this is probably true, inasmuch as no other organs have been discovered, and yet many Annulosa, as *e.g.* bees in search of distant clover, exhibit the possession of the sense of smell as well as of hearing.

No special organs of *taste* or *touch* are present, but the wings of many Annulosa are highly sensitive organs, as are the antennæ of others.

Molluscoida. Many are blind, but the Ascidians possess ocelli near the nervous ganglion. Molluscoida do not possess any other organs of special sense, except a few Ascidians which possess auditory sacs.

Mollusca. *Sight.* Mollusca often possess large prominent eyes, but the *Lamellibranchiata* are, for the most part, without eyes at all, and those, such as the Pecten, which possess them are only furnished with ocelli. The *Gasteropoda* possess simple eyes, which are situated either at the base, *e.g. Limnæus*, at the middle, *e.g. Haliotis*, or at the apex of the tentacles, as in the common snail. The *Heteropoda* and *Pteropoda* both possess eyes; in the former class they are large, and in the latter small, and situated at the back of the head. *Cephalopoda* have extremely large and prominent eyes, which are constructed like the eyes of Vertebrata, except that there is no aqueous humour, and the lens, consequently, where it is exposed by the opening of the pupil, is bathed freely by the water in which the animals swim. The lens is indeed double, one placed behind the other, a provision for increasing the refractive power of this body in the Cephalopoda.

Hearing. All Mollusca possess auditory sacs filled with fluid and containing otoliths ; the sacs are placed in communication with the cerebral ganglion. The cephalopoda are supplied with two large flask-shaped auditory sacs lodged in the cephalic cartilage, and surrounded as well as filled with fluid. The auditory nerves are large, and expand upon the auditory sacs.

Smell. The sense of smell probably resides in the tentacles of many Mollusca, but in Cephalopoda there are two little sentient papillæ placed in a cavity near the eye which receive filaments from the optic nerve, and which are regarded as organs of smell.

Taste. The odontophore of Gasteropoda and the tongue of Cephalopoda are organs of digestion rather than of taste.

ORGANS OF EXCRETION are known to exist among the Invertebrata, because uric acid has been found in the Annulosa and Mollusca and guanin in the Cœlenterata, but our knowledge of their morphology is still imperfect.

Protozoa. The skin of Protozoa is the only excretory organ.

Cœlenterata generally excrete by the ectoderm and endoderm ; but in some, small cell-like bodies project into the body cavity, which are thought to act as renal organs.

Annuloida. The water-vascular system of Annuloida is probably partially excretory in function.

Annulosa. All Annulosa (except Crustacea) possess tubes, placed near the stomach and opening into the intestine, which are perhaps homologues of renal organs, but by many are regarded as the representative of the liver.

Molluscoida do not possess specialised renal organs.

Mollusca. In *Lamellibranchs* a glandular kidney is found near the heart, whose duct opens into a pallial chamber ; *Gasteropoda* possess a similar gland, whose duct opens into another branchial cavity. *Cephalopoda* possess several spongy masses of follicles, which act as organs of excretion, placed around the branchial veins, and whose ducts open into the branchial cavity.

MODE AND ORGANS OF REPRODUCTION. **Protozoa.** Spermatozoa and ova have been observed by some naturalists in the bodies of certain Infusoria and in the substance of the Spongida ; in them consequently reproduction is by sexual congress of sperm and germ cell, but for the most part the Protozoa multiply fissiparously or gemmiparously.

Cœlenterata. *Hydrozoa. Male.* Spermatozoa lodged in small conical projections of ectoderm, and emitted from their apices. *Female.* Similar projections containing ova placed lower down; the liberated ova are at first cilated. Besides this sexual reproduction, Hydrozoa multiply by gemmation. *Actinozoa.* Similar organs are present to those of Hydrozoa, but placed on the mesenteries and not growths of the ectoderm.

Annuloida. *Scolecida. Turbellaria*: hermaphrodite. *Male organs.* Two long tubular tests with penis lodged in a sac. *Female organs.* Ovaries not distinct, but ova scattered about the body. Two branching oviducts lead to a single external opening tube or vagina. *Trematoda.* Hermaphrodite. Organs very large. *Male.* Convoluted tubular testis, whence one duct runs to the oviducts, and two ducts lead to the penis, which is lodged in a sac. *Female.* Ovary near ventral sucker. Vitellaria, or yelk-supplying organs, which run into ovary, near the commencement of the oviducts; the oviducts expand to form a uterus, and contract again to form a vagina. Metamorphosis very common, which is described at page 39. *Tæniada,* hermaphrodite. *Male.* Vesicular testis lodged in branches of dendritic ovary, and evertible penis lodged in a sac. *Female.* Much-branched ovary, occupying posterior sixth of body. Vitellaria on either side opening into ovary; the ovary leads to a uterus to which succeeds a vagina, which terminates laterally in the generative pore above the penis. Developed by alternation of generation, vide page 39. *Nematoidea.* Sexes distinct. *Male.* Long tubular testes with vesiculæ seminales, vasa deferentia, and two little penile spicules. *Female.* Large ovary, with communicating vitellaria; oviducts lead to uterus, where spermatozoa produce impregnation of the ova: the egg is enclosed in a strong case, which finally hardens into a shell. No metamorphosis during reproduction. *Rotifera.* Sexes distinct. *Male.* Testes and penis. *Female.* Large ovary, whose duct opens into cloaca. Impregnation takes place internally, and the young rotifer acquires some dimensions prior to birth. *Echinodermata.* Hermaphrodite as a rule. *Male.* Testes in each ray with vasa deferentia. *Female.* Ovaries in each ray with oviducts, which open at the angle between two rays. During development undergo metamorphosis, for which see page 47.

Annulosa. *Annelida.* Hermaphrodite as a rule. Testes and ovaries saccular organs, whose contents are discharged into perivisceral space. Each segment is furnished with a pair of these testicular or ovarian sacs. The impregnated ova are extruded through genital pores which open on the surface. *Myriapoda.* *Male.* Has seven testes and fourteen ducts, which open near the anus. *Female.* Ovary simple, and leads to tube, which opens also near the anus. No metamorphosis. *Crustacea.*

Many hermaphrodite ; in many others, however, sexes distinct. *Male.* Testes situated in the thorax, and communicating with each across the middle line ; they lead to a musculo-membranous penis of considerable size, which can be protruded through an opening in the basal joints of the last thoracic limb. *Female.* Ovaries double ; situated in the thorax, communicate with vagina, and open through the basal joints of the third ambulatory limb by a single tube. Development often takes place through a succession of moults, as described at page 61. In some, *e.g.* Cirripedia, the females carry within their own bodies husbands for life in the shape of supplementary males. *Insecta.* Sexes distinct as a rule. *Male.* Tubular testes often very much complicated ; these organs are in connection with convoluted reservoirs, or vesiculæ seminales, and lead to vasa deferentia, which eject their contents through a urethra which traverses a conical penis, enclosed between two of the abdominal plates. *Female.* Tubular ovaries attached by mesenteries, lead to oviducts, which open into a single uterus and give succession to a vaginal orifice. A spermotheca, or germ-reservoir, is in connection with the uterus. Most Insecta pass through a metaphosis of larva, pupa, and imago, for details of which see page 67. *Arachnida.* Sexes distinct. *Male.* Testes abdominal, and efferent ducts open between thorax and abdomen : semen is conveyed by maxillary palpi to the vulva of the female. *Female.* Ovaries abdominal, and open in a similar position to the testes of the male.

Molluscoida. *Ascidioida.* Hermaphrodite. *Male* and *Female* organs very similar and much interwoven. Reproduction is sometimes by gemmation, sometimes by union of sperm and germ cells. *Brachiopoda.* Hermaphrodite. Organs somewhat similar to those of Ascidians, but reproduction always sexual. *Polyzoa.* Hermaphrodite. *Male.* Testes lobular and irregular, connected to stomach and to body-wall. *Female.* Ovary circular with duct. Impregnation internal, and polyzoon considerably developed before the ovum is extruded ; the embryo escapes through a rent in the body-wall and not through a duct. Reproduction sometimes by union of sperm and germ cell, sometimes by gemmation.

Mollusca. *Lamellibranchiata.* Diœcious. Testes and ovaries situated along intestine ; no sexual congress ever takes place, but reproduction occurs within the pallial covering, or in a pouch on the branchiæ, or in cloaca, or outside the parent. *Gasteropoda.* Monœcious and diœcious. *Male* organs. Tubular convoluted penis, vasa deferentia, evertible penis. *Female.* Tubular ovary, oviducts with spermotheca attached, and vaginal outlet.

The egg is often covered with much albumen, which serves as yelk food. *Pteropoda.* Hermaphrodite. *Cephalopoda.* Sexes distinct. *Male* possesses a hectocotalytic arm, which holds a sac filled with spermatozoa ; this becomes applied to the oviduct of the female, and the arm, with the contained sac, is left adherent to the female. *Female.* Ovary, oviduct, nidamental gland all present ; the generative opening is in the branchial chamber.

CHAPTER XX.

TABULAR VIEW OF THE PRINCIPAL DIVISIONS OF THE INVERTEBRATA.

SUB-KINGDOMS, CLASSES, AND ORDERS OF INVERTEBRATA.

SUB-KINGDOM I. PROTOZOA.

Class I. GREGARINIDA.

Class II. RHIZOPODA.

Orders.
1. Monera.
2. Lobosa.
3. Reticularia.
4. Radiolaria.

Class III. SPONGIDA.

Class IV. INFUSORIA.

1. Ciliata.
2. Suctoria.
3. Flagellata.

SUB-KINGDOM II. CŒLENTERATA.

Class I. HYDROZOA.

Sub-Class A. *Hydroida* . .	1. Hydrida. 2. Corynida. 3. Sertularida.
Sub-class B. *Syphonophora* . .	4. Calycophorida. 5. Physophorida.
Sub-Class C. *Discophora* . .	6. Lucernarida.

Class II. ACTINOZOA.

1. Zoantharia.
2. Alcyonaria.
3. Rugosa.
4. Ctenophora.

SUB-KINGDOM III. ANNULOIDA.

Class I. SCOLECIDA.

Sub-Class A. *Platyelmia* . .	1. Tæniada. 2. Trematoda. 3. Turbellaria.
Sub-Class B. *Nematelmia* . .	4. Acanthocephala. 5. Gordiacea. 6. Nematoidea.
Sub-Class C. *Rotifera* . . .	7. Rotifera.

Class II. Echinodermata.

Orders.

1. Echinidea.
2. Asteridea.
3. Crinoidea.
4. Ophiuridea.
5. Holothuridea.

Sub-Kingdom IV. ANNULOSA.

Class I. Annelida *vel* Anarthropoda.

1. Errantia.
2. Tubicola.
3. Terricola.
4. Suctoria.
5. Gephyrea.

ARTHROPODA.

Class I. Crustacea.

1. Podophthalmia.
2. Edriophthalmia.
3. Stomapoda.
4. Branchiopoda.
5. Ostracoda.
6. Cirripedia.
7. Copepoda.
8. Merostomata.
9. Trilobita.

Class II. Myriapoda.

1. Chilopoda.
2. Chilognatha.
3. Pauropoda.

Class III. Insecta.

Sub-class A. *Ametabola* . .	1. Anopleura. 2. Mallophagi. 3. Thysanura.
Sub-class B. *Hemimetabola* . .	4. Hemiptera. 5. Orthoptera. 6. Neuroptera.
Sub class C. *Holometabola* . .	7. Aphaniptera. 8. Diptera. 9. Lepidoptera. 10. Hymenoptera. 11. Strepsiptera. 12. Coleoptera.

Class IV. Arachnida.

1. Pautopoda.
2. Linguatulina.
3. Tardigrada.
4. Acarina.
5. Pedipalpi.
6. Araneina.

SUB-KINGDOM V. MOLLUSCOIDA.

Class I. ASCIDIOIDA.

Orders.
1. Branchialia.
2. Botryllida.
3. Appendicularia.

Class II. BRACHIOPODA.

1. Articulata.
2. Inarticulata.

Class III. POLYZOA.

1. Phylactolæmata.
2. Gymnolæmata.

SUB-KINGDOM VI. MOLLUSCA.

Class I. LAMELLIBRANCHIATA.

1. Siphonida.
2. Asiphonida.

Class II. GASTEROPODA.

Sub-Class A. *Branchio-Gasteropoda*
1. Prosobranchiata.
2. Opisthobranchiata
3. Heteropoda.

Sub-Class B *Pulmo-Gasteropoda* .
4. Inoperculata.
5. Operculata.

Class III. PTEROPODA.

1. Thecosomata.
2. Gymnosomata.

Class IV. CEPHALOPODA.

1. Dibranchiata.
2. Tetrabranchiata

CHAPTER XXI.

SUB-KINGDOM: VERTEBRATA—GENERAL CHARACTERISTICS—SKELETON WITH ITS HOMOLOGIES.

VERTEBRATA. *Definition.* Animals that possess a vertebral column, formed by the coalescence of vertebræ; or, more universally, animals that possess at some period of their existence a fibro-cellular rod tapering to either end, situated in the site of the future vertebral bodies, when they exist, and called the *notochord.* All Vertebrata do not possess limbs; when they do, they never exceed two pairs. The skeleton which gives attachment to the muscles is always *internal.* The heart contains red corpusculated blood, and is composed of two or more cavities. A portal *venous* system is always present. The *respiratory organ* communicates with the pharynx. The *alimentary canal* is always provided with a distinct inlet and outlet. The *nervous system* is much more largely developed than in the highest of the Invertebrata; it is lodged in the vertebral column, and in its expanded upper portion, termed the cranium, and consists of a brain and spinal cord.

Relative Position of Parts.—If a transverse section be made of an invertebrate animal, all the structures or organs will be found contained in one tube and observing a regular order. Thus from behind forwards we have: 1, the hæmal system; 2, the alimentary canal; and 3, most anterior of all, the nervous system. If now a transverse section be made of any vertebrate animal, it will be seen that the organs are contained in two quite distinct tubes, the anterior of which conforms to the single tube of invertebrates, the posterior being a completely fresh structure and containing a spinal cord and brain. The anterior and larger tube, although it possesses the same structures as the invertebrate tube, has them differently arranged; thus, from behind forwards, we come first to the ganglionic nervous system, which is clearly homologous with the single nervous system of Invertebrata, then to the hæmal system, and in front of all to the alimentary canal. It must, however, be conceded that although the nervous system of Invertebrata is homologically represented by the ganglionic or sympathetic system of vertebrates, yet the nervous system of an invertebrate performs many functions of a reflex character, such as sensori-motor, excito-motor, and even ideo-motor actions, which in vertebrates are performed by the cerebro-spinal system alone; from which it follows that, *analogically*, the nervous system of Invertebrata represents both the ganglionic and the cerebro-spinal system of vertebrates.

The *blood* of vertebrates is always red—except in Amphioxus—and contains red cells, which are oval or circular; they are largest in amphibia and fish, and smallest in mammalia. The Proteus has the largest corpuscles of any vertebrate, the Musk-deer the smallest. In the former they measure $\frac{1}{330}$ of an inch in length; in the latter they are but $\frac{1}{12325}$ of an inch in diameter.

Circulation.—Although the heart of a vertebrate may contain two cavities (fishes), three (reptiles), or four cavities (birds and mammals), it is, nevertheless, always a *respiratory* heart in the first instance; in other words, the ventricle always pumps the blood first to the gills or lungs, as the case may be, in order to secure its purification prior to distributing it over the entire system, whereas, as we have seen, the heart of invertebrates is invariably a *systemic* heart; in other words, the ventricle first propels the blood over the whole body before it is submitted by the capillaries to the oxygen contained in the air or water, according as the animal possesses an aërial or aquatic respiratory apparatus. Taking man as our type, the course of the circulation is as follows: the right ventricle contracting, forces the blood into the pulmonary arteries, which distribute it through a most intricate capillary network to the ultimate structure of the lungs, whence it is returned by four veins to the left auricle, a cavity which forthwith discharges it into the left ventricle placed beneath. This strong muscular cavity then ejects the blood with such force into the aorta, as to distribute it through the systemic capillary system to the entire body, where, having done its work by feeding the tissues and providing for the secretions, it is returned by veins into the right auricle, which in turn transmits it to the right ventricle, and so completes the magic circle.[1]

Digestive System.—The manducatory organs of vertebrates are never hard or horny productions of the alimentary canal,

[1] Professor Haughton calculates that the total work done by the heart of man in twenty-four hours is equal to lifting 124·208 tons through one foot of space.

nor do they ever subserve the functions of limbs, as they so often do in invertebrates.

Kidneys are always present; in the lower orders, consisting of medullary portions alone; in the higher, of both cortical and medullary elements.

Nervous System.—The ganglionic system, before referred to, supplies the unstriped muscles and presides over organic or visceral life; the cerebro-spinal system supplies the striated muscular fibre, and reigns over animal or sentient life. All four *senses* are present, except in a few Amphibia, which are blind.

Skeleton.—The skeleton is primarily divided into the *axial*

Fig. 40.

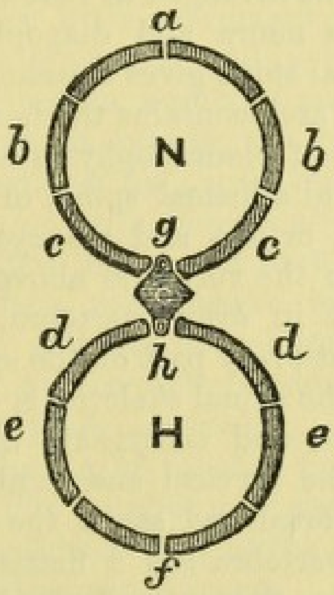


DIAGRAM OF A TYPE VERTEBRA, FROM OWEN.

N. Neural Arch. *H.* Hæmal Arch. The Centrum is placed between *g* and *h*. *c. c.* Neurapophyses. *b. b.* Diapophyses. *a.* Neural spines. *d. d.* Pleurapophyses. *e. e.* Hæmapophyses. *f.* Hæmal spines.

and the *appendicular* skeleton; the former being the skeleton of the trunk, the latter that of the limbs.

The trunk and head are composed of segments called vertebræ, serially arranged, which are variously modified to subserve various purposes in different situations, but which all contain certain similar parts or elements. It is convenient to picture an ideal or typical vertebra, and to describe it so that others may be compared with this central figure, not necessarily because there *is* a typical or archetypal vertebra toward which all vertebræ are tending and striving, but merely for the sake of convenience of description. A typical vertebra, then, consists of the following parts:—There is, in the first place, a central mass called the body or *centrum*, from which extends an upper and a lower bony arch; the upper lodges the spinal cord and is called the *neural* arch; the lower contains the vascular system, and is termed the *hæmal* arch; spinous processes called respectively the *neural* and the *hæmal spinous process* project from their respective arches. The neural arch consists on each side of two connected pieces, the *diapophyses* and the *neurapophyses*.

The hæmal arch likewise presents for our examination two bones, the *pleurapophyses* and the *hæmapophyses*. Four other processes, two on either side, called *zygapophyses*, project from the junction of the diapophyses with the centrum, and from the junction of the pleurapophyses with the centrum. Considering that we are taking a dorsal vertebra of man as our type, the different parts would be arranged as follows: The neural arch contains the cord, its neura and diapophyses constitute the laminæ, and the neural spine gives attachment to the muscles of the spine; the hæmal arch contains the heart, grēat vessels, and lungs, and is made up of pleurapophyses or ribs, hæmapophyses or costal cartilages, and a hæmal spine, or sternum. The two upper and two lower, or *pre-* and *post-zygapophyses* are joined to similar processes on the vertebræ above and below.[1] These parts are not present in every vertebra, and there are some modifications in almost every part of the spine. Still, speaking of man as our type, the spinal skeleton is divided into cervical, dorsal, lumbar, sacral, and coccygeal, or, in other animals, caudal vertebræ. The cervical and lumbar vertebræ are the most movable, the dorsal and sacral the most fixed. In the cervical region each vertebra has a flattish body and a large neural canal, but no elements of the hæmal arch whatever are present.

The first cervical vertebra is called the *atlas*, and articulates by two cups with the condyles of the occipital bone of the skull. The atlas consists of nothing but two arches separated by a ligament: the posterior, large one, for the cord; the anterior, small one, for the reception of a vertical piece, the *odontoid* process of the vertebra next below. This second cervical ver-

[1] The *elements* of a vertebra are those parts which develop from a separate centre of ossification, and are therefore called 'autogenous.' The *processes* of a vertebra grow from already ossified parts, and are therefore termed 'exogenous.' The *elements* of a vertebra are the centrum, the neurapophyses, the neural spine on the upper arch, and the pleurapophyses, the hæmapophyses, and the hæmal spine on the lower arch. The *processes* are the diapophyses, the parapophyses, the zygapophyses, the anapophyses, the metapophyses, the hyapophyses, and the epapophyses.

tebra is called the *axis*, and is peculiar in possessing the singular vertical or odontoid process just spoken of. Development proves this to be in reality the body of the atlas displaced from its true position. The cervical vertebræ are almost invariably seven in number, whatever the length of the neck, whether it be extremely long like that of the giraffe, or like that of the porpoise, reduced to a minimum; the exceptions being the three-toed sloth, which has nine cervical vertebræ; the two-toed sloth, and the manatee, which have six. In Sauropsidans the number is greater, and sometimes there are as many as twenty-five, as in the swan. In Batrachia there is but one cervical vertebra, and fishes cannot be said to possess any.

In the *dorsal* region the neural spines are very long and overlap, so that very little movement is possible here; the hæmal arch, however, is present, and is very large. The dorsal vertebræ vary very much in number; man, and the majority, have twelve, the elephant twenty, the two-toed sloth twenty-four, one of the armadillos, ten; some birds having a very small number, nine, seven, or, as in *Ciconia alta*, only three.

In the *lumbar* region the hæmal arch is again suppressed; the bodies are very large and massive, to support the increased weight of the trunk, and the neural spines are horizontal, so that the bones enjoy considerable freedom of movement. The number of lumbar vertebræ is variable. The average number, as in man, is five. The largest number in quadrupeds is nine, as in the slow-lemur. The number may rise to twenty-four, as in the dolphin, or fall as low as four in the apes, three in the two-toed sloth, or two in the monotremata.

The *sacral* vertebræ are welded together to form a single solid wedge-shaped bone, the sacrum, which lodges the termination of the cord, and supports the pelvis, to which are attached the lower limbs. The sacral vertebræ, which number five in man, may rise as high as twenty in the ostrich. The highest apes have six, and one of the armadillos ten. In birds the number usually falls as low as three. The sacrum is wanting in fish with the exception of the turbot, which makes an attempt at the formation of a sacrum by the union of two coccygeal vertebræ.

The *coccygeal* vertebræ vary more than those of any other region of the spinal column. In the human subject we usually find five segments in this region; this may be reduced in the maggot to three, in some bats to two, and in the frog to an attempt at a coccyx caused by ossification of the membrane surrounding the notochord. On the other hand, it may be increased to forty-six in the manis, in the spider-monkey thirty-three, and in some sharks it may even reach to 270 separate vertebræ.

The *cranial* skeleton consists of the bones of the skull and the bones of the face ; they are numerous and complicated, and vary widely in the different classes and orders of vertebrates, but the same elements are as a rule distinctly recognisable—that is, we can, as a rule, determine the homologies of the bones of various crania. The segments of the skull nearest to the spine are clearly made up of modified vertebræ, but as we advance further and further from the spine, the succeeding segments become less and less like vertebræ. It is, however, the belief of many naturalists that the entire cranium is made up of modified vertebræ ; others, on the contrary, consider that the cranial vertebræ do not extend beyond the second or parietal segment. It is certain, however, that the same elements can be made out in the front as in the hind parts of the skull, and as the description of different crania is much facilitated by having a regular nomenclature, the cranial vertebrate theory in its entirety is here adopted.

We must first speak of the bones which enter into the composition of the skull, still taking man as our type, before referring to the vertebral homologies of the separate bones. The cranial skeleton consists of bones of the skull, or calvarium, and bones of the face. The skull consists of eight bones—four single and two double.

The *Occipital* bone forms the occiput or back of the head ; it is not unlike a large scallop shell, with a hole as big as half-a-crown at the base. The hole is the foramen magnum, and transmits the commencement of the spinal cord and its membranes, two vertebral arteries, and the two spinal accessory nerves. On either side of this foramen, the *condyles* are placed, which articulate with the cups on the atlas. The bone in front of the foramen magnum is united to the body of the *sphenoid*, which is the next succeeding segment. Behind the foramen the occipital bone is expanded to support the cerebellum, and above this, the hinder part of the cerebrum. Many muscles, which pass from the spine to the skull, and serve to keep the head erect, are attached to the outer surface of the occipital bone.

The *Parietal bones* form the greater part of the vertex and sides of the skull ; they are quadrangular, flat, but slightly curved bones, articulating with each other on the top of the skull, joining the occipital behind, the frontal in front, and the temporal and sphenoid below.

The *Frontal* forms the forehead, and the upper part or roof of the orbits; between the two orbits the root of the nose is placed.

The *Temporal* bones are placed one on either side of the skull, and have the opening of the ear passing into them. From their outer surface a thin bow of bone, the 'zygoma,' passes like a flying buttress from the side of the skull to the cheek bone. The internal ear is also contained in the temporal bone, lodged in a pyramidal process, which passes inwards towards the middle line of the base of the skull, the apices of the two pyramids being only separated by a narrow stem of bone, the *sella turcica*, half-an-inch in width.

The bone behind the opening of the ear is called the *mastoid*, the part above the *squamous*, and the pyramidal process the *petrous* bone. The relations of the different parts of this bone to the organ of hearing, which is intercalated between the occipital and the parietal segments, are full of importance, and, must be specified. The upper part of the *petrous portion*, seen from within, surmounts a little depression of the middle ear, the 'fenestra ovalis,' and is called *pro-otic* (πρό, before οὖς, ὠτός, the ear). The lower part of the petrous portion, seen from beneath, and hollowed by the carotid canal, forms the lower boundary of the fenestra ovalis, and is called *opisthotic* (ὄπισθε behind). The mastoid portion, which also contains the superior semicircular canal, is the *epiotic* (ἐπί, above).

The *Sphenoid* (σφήν, a wedge) is often likened to an animal with a small body, two depending legs, and two pairs of wings. The body is ossified to the occipital bone behind, and joined to the *Ethmoid* in front; it is hollowed out into a pit called the *sella turcica*, which lodges the pituitary body; the legs are the pterygoid processes; they form buttresses behind the posterior nares, and serve to lodge the pterygoid muscles, which are powerful muscles of mastication. The wings spread out on either side: the greater form part of the sides of the skull, and also the outer wall of the orbit; the lesser, placed at the base of the skull, support part of the anterior cerebral lobes.

The *Ethmoid* (ἠθμός, a sieve) is placed in front of the Sphenoid bone; it forms the septum of the nose, and contains the organ of smell. Its upper *cribriform plate* is placed at the base of the skull, the central plate which hangs down is the *vertical plate*, the delicate sieve-like bones on either side are the *superior* and *middle turbinated*, and the outer smooth surfaces the *ossa plana*. The latter forms the chief part of the inner wall of the orbits.

The face consists of fourteen bones—two single, and six double. The *Maxillary* bones, called in Anthropotomy *superior maxillary*, form the chief part of the upper portion of the face.

They complete the margins of the orbits and of the nose ; they form the upper jaw, and lodge the upper teeth ; they form a large part of the cheek, and contain a large cavity in their interior called the *Antrum of Highmore.*

The *Malar* or *jugal* bones form the prominences of the cheeks, articulating with the zygoma, the frontal, the sphenoid, and the superior maxilla.

The *Lachrymal bones* are small bones developed from mucous membrane, placed on the inner wall of the orbit, and hollowed out by the lachrymal duct.

The *Nasal bones* form the bridge of the nose.

The *Palate bones* are placed at the inner and back part of the maxillæ, entering into the formation both of the roof of the palate and the floor of the orbit ; they are wedged between the maxillæ and the pterygoid processes.

The *Vomer* is a single median bone, regarded by some as being one of the true cranial bones ; it is shaped like a ploughshare, articulates with the sphenoid behind, and runs forwards between the nares, completing the partition between the two with the assistance of the ethmoid, and the triangular cartilage in front.

The *Inferior turbinated* bones are curled bones placed in the nostrils on either side of the nasal process of the maxillæ.

The *Mandible*, or as it is called in Anthropotomy, *Inferior Maxilla*, is a single bone, and forms the lower jaw : it lodges the teeth, and is articulated by a movable joint to the temporal bone of the skull.

Now looking upon the cranial skeleton as made up of vertebræ, the bones of the skull belong to the neural arches, and the bones of the face to the hæmal arches of the typical vertebra. There are then four cranial vertebræ, each lodging a distinct part of the nervous centres, and termed from behind forwards, the *occipital*, *parietal*, *frontal*, and *nasal* vertebræ ; the corresponding portions of encephalon being termed *epencephalon, mesencephalon, prosencephalon*, and *rhinencephalon.*

The neural arch of the occipital vertebræ consists of a centrum, the *basi-occipital*, two neurapophyses, the *exoccipitals*, a neural spine, the *superoccipital*, and two diapophyses, the *paroccipitals.* In man all these are blended into one bone, the *occipital.* The hæmal arch of this same vertebra consists of the pleurapophyses, the *supra scapula*, and *scapula*, and the hæmapophyses, the *coracoid* bone. The whole arch is called the *scapular arch*, and supports the upper limb, which is thus supposed to be appended to the occipital bone, such being actually the case in many Fishes.

The neural arch of the parietal vertebra consists of a centrum, the *basisphenoid*, which is connected by bone with the basioccipital; two neurapophyses, *alisphenoids*, the neural spine, the *parietal*, and two diapophyses, the *mastoid* bones (which in many animals are quite distinct from the other parts which go to form the temporal bone of man). The ear-case is wedged between this segment and the occipital vertebra. The hæmal arch consists of a double pleurapophysis, the separate pieces being called (in fish) the *stylohyal* and *epihyal*, a hæmapophysis, or *ceratohyal*, and a hæmal spine, the *basihyal*. Fish very often develop a bone in front and behind this basihyal, the former of which is called the *glossohyal*, and the latter the *urohyal*. The entire hæmal arch is called Hyoidean, because it supports the hyoidean apparatus.

The neural arch of the frontal vertebra consists of a centrum, the *presphenoid*, two neuropophyses, the *orbitosphenoids*, a neural spine, the *frontal* bone, and two diapophyses, the *post frontals*.

The hæmal arch consists of a pleurapophysis, which in Fish is subdivided into an upper part, called *epitympanic*, a central, or *mesotympanic*, a fore, or *pretympanic*, and a lower, or *hyotympanic*. No other class of vertebrates have such a complicated hæmal arch as this; in most, indeed, the pleurapophysis consists of a single bone. The hæmapophysis, which succeeds the pleurapophysis, is likewise divided into two, the first called the *articular*, and the second the *dentary* bone. The latter in Fish supports another bone called the *angular*. The entire hæmal arch is called *mandibular*, because it forms the lower jaw; in fishes it supports the *opercula*, or gill-covers.

The nasal vertebra is probably not a vertebra at all, even if the preceding is one: at least development supports the belief that the cranial vertebræ stop at the parietal segment, inasmuch as the notochord, from which the vertebræ are all developed, only extends as far as the *sella turcica* of the vertebrate skull, and stops short of the entire segment known as the frontal vertebra. Considering, however, for the sake of uniformity, that the nasal vertebra is a reality, its neural arch consists of a centrum, the *vomer*, two neurapophyses, the *prefrontals*, and a neural spine, the *nasal* bones; the hæmal arch of pleurapophyses, the *palatines*, a hæmapophysis, the *maxillary*, and a hæmal spine, the *premaxillary* bone. The hæmal arch is called *maxillary*, and supports the *pterygoid* bones as appendages.

The three sense organs—the nose, or rather olfactory region, the eye, and the ear—are intercalated between the bones of the brain case. 1. The olfactory mucous membrane ossifies into the *turbinals*, and is placed beneath the nasal vertebra. 2. The eye capsule, formed by skin, between the frontal and parietal bones.

And 3, the ear, enclosed in the periotic capsule, between the parietal and occipital vertebræ. The eighth nerve always passes out of the skull immediately behind the periotic capsule, the fifth always just in front. In mammals, the lower jaw articulates into the skull directly, but in Birds and Reptiles a bone called the *quadrate* intervenes between the mandible and the skull.

Some naturalists, rejecting the vertebrate theory of the skull, see in the so-called hæmal arch of the frontal vertebra the homologue of the bones of the middle ear; with them the hyotympanic is the *incus*, the articular bone is the *malleus*, the mesotympanic the *stapes*, and the pretympanic the *orbicular*. Others again, rejecting this theory, yet recognise in the incus the os quadratum.

Again, the paroccipital is believed by many to be the homologue of the mastoid and the so-called mastoid is identified with the squamosal bone.

The post-frontal is not represented in human anatomy. Besides these bones there are many dermic facial bones in fish and other vertebrates, sometimes, as in the *gurnard*, forming a complete case; even in man one of these dermic bones is present, viz., the lachrymal.

Placing them tabularly then we should have the following arrangement of elements in the four cranial vertebræ which we have now reviewed. (See Table on next page.)

The *Appendicular Skeleton* is composed of the scapular arch, which supports the fore limbs, and the pelvic arch, to which the hind limbs are attached. The scapular arch or shoulder girdle in man consists of the scapula or shoulder-blade, and the clavicle or collar-bone; but in most vertebrates there is a third important element, the coracoid bone, which in man has become a small process of the scapula, called the coracoid process.

Still regarding man as the type, we notice that the *scapula* is a flat triangular bone slung loosely among the muscles of the back lying on the back of the six upper ribs and supporting the humerus externally by a large socket, the glenoid cavity. A prominent buttress, the *spine*, traverses the back of the scapula, and rises into a prominence externally, the acromion process, which overhangs the shoulder-joint and articulates with the clavicle.

The *Clavicle*, when present, is a slender bone serving to keep the shoulders apart, and extending between the sternum and the acromion process of the scapula.

The upper limb consists of a *humerus* or arm-bone, two bones of the forearm, the *radius* and *ulna*, a wrist or *carpus*, a *metacarpus*, and of *phalanges* or fingers.

		Type Vertebra	*Nasal Vertebra*	*Frontal Vertebra*	*Parietal Vertebra*	*Occipital Vertebra*
Neural Arch		Neural Spine .	Nasal Bone (Nose)	Frontal Bone (Eye)	Parietal Bones (Ear)	Supra-occipital
		Diapophysis .	— (Nose)	Post Frontal (Eye)	Mastoid or Squamosal (Ear)	Paroccipital
		Neurapophysis .	Prefontal (Nose)	Orbitosphenoid (Eye)	Alisphenoid (Ear)	Exoccipital
C.		Centrum . .	Vomer	Pre-sphenoid	Basi-sphenoid	Basi-occipital
Hæmal Arch		Pleurapophysis .	Palatine	Epi-tympanic, meso-, hyo-, and pre-tympanic	Stylo-hyal and Epi-hyal	Supra Scapula and Scapula
		Hæmapophysis .	Maxillary	Articular and Dentary	Cerato-hyal	Coracoid
		Hæmal Spine .	Pre-maxillary	—	Basi-hyal	—
Appendages			Pterygoid Bones	Mandibular Apparatus	Hyoidean Apparatus	Pectoral Limb

The *Humerus* is a long bone with a round head above, lodged in the glenoid cavity, an expanded and flattened lower extremity, presenting a trochlear or pulley-like surface for articulation with the ulna, and a small head or capitellum for the radius. A slightly twisted shaft connects the extremities: at the upper part of the shaft two rough eminences, or bosses of bone, are placed, called the greater and lesser tuberosities; these give attachment to the rotator or rolling muscles of the arm: the greater being placed on the radial, and the lesser on the ulnar side of the limb. The *outer* surface of the humerus at its lower part gives origin to the *supinator* and *extensor* muscles of the hand: the internal surface to the *pronator* and *flexor* muscles.

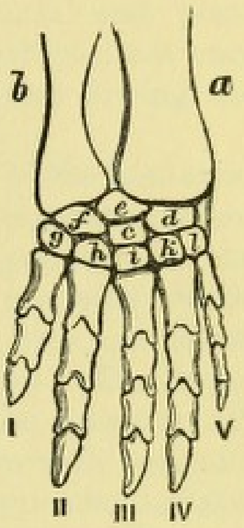
The *Radius* is the outer bone of the forearm: it has a small head above where it articulates with the humerus, and a large expanded surface below where it forms the chief part of the surface for articulation with the wrist. A small but prominent tuberosity is placed at its upper part on the ulnar side, called the bicipital tuberosity for the insertion of the biceps muscle. The radius can be slung round the ulna, carrying the wrist with it; when it is so slung that the palm of the hand looks downwards, the movement is called *pronation*; when slung in the opposite direction so that the palm looks upwards, the action is styled *supination*.

The *Ulna* is the inner and larger bone of the forearm, forming the entire prominence of the elbow above, but is very small below and separated from the wrist joint by a small interarticular fibro-cartilage.

The *Carpus*, or wrist, is composed of eight bones, disposed in two rows, the upper bones being called from the radial to the ulnar side *scaphoid*, *semilunar*, *cuneiform*, and *pisiform*, and the second row in the same direction, *trapezium*, *trapezoid*, *os magnum*, and *unciform*. It is now held, however, that the typical arrangement of the carpus is for it to consist of nine bones, one being central, and having three above it and five below. Such, for example, is the case in the Tortoise, the central bone is called *os centrale*, the three upper, beginning at the radial side, *scaphoid*, *lunare*, and *cuneiform*, and the five lower, *trapezium*, *trapezoid*, *os magnum*, and *unciform*, which last is divided into two. The *Metacarpus* is composed of five long bones which articulate with the wrist posteriorly and with the phalanges anteriorly: they give attachment to the muscles of the palm of the hand and of the thumb and little finger. The *Phalanges* also consist of five sets, each finger having three, a proximal, a median, and a distal phalanx, except the thumb, which has but two ; unless, as is indeed likely, the thumb has no metacarpal bone, in which case it would possess the full complement of phalanges.

The *Pelvic arch* is composed of three bones, the *Ilium*, *Ischium*, and *Pubes*, soldered together, and of the *Sacrum* ; together they form the strong bony basin or Pelvis, which supports the lower limbs. The Pelvic arch, unlike the Scapula, is not loosely slung among the muscles of the back, but is firmly articulated to the spine. The *Ilium* forms the flangeing part of the hip ; the *Ischium* is the lower part of the bone, on which we rest in sitting : and the *Pubis* is the smallest part of the bone, placed in front, and meeting its fellow of the opposite side at the *symphysis* ; this pubic bone supports the external organs of generation. All three meet to form the deep cup of the *acetabulum* or cotyloid cavity with which the thigh bone is articulated. The lower limb consists of the Femur the Tibia and Fibula, a Tarsus, a Metatarsus, and Phalanges.

Fig. 41.



FORE-FOOT OF A CHELONIAN REPTILE.

a. Ulna. *b.* Radius. *c.* Centrale. *d.* Cuneiform vel ulnare. *e.* Lunare vel intermedium. *f.* Scaphoid vel radiale. *g.* Trapezium. *h.* Trapezoid. *i.* Os magnum, *k. l.* Divided unciforme.

The *Femur*, or thigh-bone, is the longest bone in the body. It has a globular head, a slightly-twisted shaft, and a flattened expanded inferior extremity which enters into the composition of the knee-joint. Just below the head two prominences are placed, larger than the corresponding humeral elevations, and called the greater and lesser *trochanters* ; the greater is placed on the outer or fibular side, the lesser on the inner or tibial side. The flattened expanded ends of the Femur are called, like the corresponding processes of the Humerus, the external and internal Condyles.

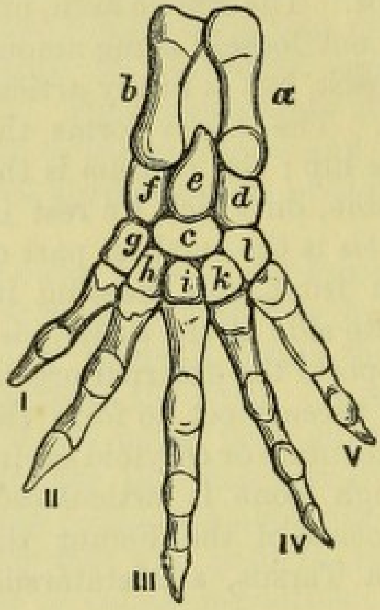
The *Tibia* is the inner and much larger bone of the leg : *above* together with the Femur and Patella, it forms the knee-joint, the Fibula not forming any part of the joint, *below* it forms the inner ankle, and articulates with the upper surface of the astragalus. The *Fibula*, or splint-bone of the leg, is placed on the outer side ; it is a very slender bone, not entering into the knee, but forming the whole of the outer ankle.

The Tarsus is formed of seven small bones : the *astragalus* articulates with the Tibia, the *scaphoid* in front, and the *os calcis* below ; the *scaphoid* articulates anteriorly, with three *cuneiform* bones which support an equal number of *metatarsal* bones;

the os calcis, which forms the heel, is connected anteriorly with the *cuboid*, which supports the two outer metatarsal bones.

The *Metatarsal bones* and the *Phalanges* are similar in number and arrangement to those of the upper extremity.

Fig. 42.



HIND-FOOT OF AN AMPHIBIAN.

a. Fibula. *b*. Tibia. *c*. Centrale. *d*. Fibulare. *e*. Intermedium. *f*. Tibiale. *g*, *h*, *i*, *k*, *l*. Distal tarsalia. I. II. III. IV. V. Digits.

As has been stated already, Owen teaches that the limbs are appendages to the skeleton, the scapular arch supporting the pectoral limb being the hæmal arch of the first or occipital vertebra. Mr. Parker, however, in his illustrious monograph, appears to have disproved this theory, and demonstrated the fact that the shoulder girdle, consisting of the scapula behind, the coracoid bone in front, and the sternum in the middle, really belongs to the true endoskeleton, while the clavicle and interclavicle are merely membrane or dermic bones. He further shows that the bones uniting the scapular arch to the cranium, and called the supra-scapula and scapula, are also dermic bones, which he calls *post scapula* and *supra clavicle* ; the coracoid also is dermic, and this he styles the *clavicle*, while the veritable scapula and coracoid are found in small cartilage bones further removed from the skull and called by Owen the *radius* and *ulna*.

The appendicular skeleton, like the axial skeleton, is divided into pre-axial and post-axial parts, which in the upper limb are thus arranged.[1] Taking man, *e.g.*, when the thumb is directed forwards and the limb hangs down, if a line be drawn from the middle of the glenoid cavity of the scapula to the end of the middle finger, all in front of this line is *pre-axial* and all behind *post-axial*. The same bones which are pre-axial and post-axial in man are pre-axial and post-axial in all other vertebrates, but their apparent position may be altered by a twisting of the limb taking place during development.

By this we find that the greater tuberosity of the humerus, half the shaft and the outer condyle, the radius, the scaphoid and lunare, trapezium, trapezoid, and os magnum, with the corresponding metacarpals and their digits, are *pre-axial* ; while the lesser tuberosity of humerus, inner condyle, ulna, cuneiform and two metacarpals and two digits are *post-axial*. The ilium, ischium, and pubes correspond to the bones of the scapular arch thus : ilium is homologous with scapula, ischium with coracoid, and pubes with the clavicle. Looking at the appendicular skeleton of the lower limb, we find that the lesser trochanter and the inner condyle of the femur with the intervening shaft, the tibia, the astragalus and scaphoid, the three cuneiform bones, and the three corresponding metatarsals and digits are all *pre-axial*, while the greater trochanter, and outer condyle of femur, the fibula, the os calcis, the cuboid, and the two outer metatarsal bones and digits are *post-axial*.

Homologies of these Bones.—The femur corresponds to humerus ; tibia to radius ; fibula to ulna ; os calcis and astragalus to scaphoid and lunare ; scaphoid of foot to os centrale of hand when present ; cuboid to cuneiform ; the internal cuneiform to trapezium ; middle to trapezoid ; and the external to os magnum. The metacarpal and metatarsal bones, and the phalanges of the upper and lower limbs are all homologous.

[1] In considering the pre-axial and post-axial parts of any vertebrate a line must be drawn at right angles to the spine : all in front of this line is pre-axial, all behind post-axial.

CHAPTER XXII.

MUSCULAR SYSTEM OF VERTEBRATA—DEVELOPMENT OF NOTOCHORD AND SKELETON.

Muscles of Vertebrates.—The muscles of Vertebrata, which are supplied by the cerebro-spinal system of nerves, are all of the striated or voluntary kind. Although their arrangement is extremely complicated in the higher classes, yet they present some features in common, to which brief attention will here be called. The muscles, broadly speaking, are arranged round two principal axes, the axial skeleton and the appendicular skeleton. The axial muscles spring at their developmental origin from the proto-vertebræ; they correspond in number to the vertebral segments, and are called *myocommas* or *myotomes.* In most of the Vertebrate classes this arrangement is only clearly traceable at an early period of development; but in Fishes it is preserved in its primitive simplicity throughout the whole of life. These trunk-muscles are divisible into those above the axial skeleton, *epaxial*; and into those beneath it, *hypaxial* muscles. Throughout the Vertebrata the muscles of the back (erectors of the spine for the most part) belong to the epaxial set, and the parietal muscles of the abdomen and chest to the hypaxial set.

Approaching the head, we find that the mandible is depressed by the *digastric* muscle, *panniculus carnosus,* and other muscles —as, *e.g.*, in man by the *genio-hyoid* and *mylo-hyoid.* Passing from the hyoid bone to the under surface of the chin, the lower jaw is raised by the *temporal*, *masseter*, and *pterygoid* muscles. The facial muscles proper are cutaneous muscles and not connected with the axial skeleton. In regard to the trunk, the *erectores spinæ*, with their numerous prolongations, constitute the epaxial muscles, while the hypaxial series are the *anterior recti, longus colli transversalis abdominis, psoæ,* and probably the *diaphragm* and *levatores ani.*

Muscles of Appendicular Skeleton.—The muscles of the limbs are arranged dorsally and ventrally, supposing the limbs to be extended at right angles to the trunk, and are divisible into a *pre-axial* and a *post-axial* set ; *i.e.* all those muscles which in man are superior and in quadrupeds anterior to a line drawn at right angles to the axis of the trunk are pre-axial, all those which are inferior or posterior are post-axial. The pre-axial muscles are the following : *cleido mastoideus*, from mastoid bone to clavicle ; *trapezius*, from occiput to cervical and dorsal spines; *rhomboidei*, from dorsal spines to scapula ; *recti abdominales*, from pubes to sternum ; *obliquus externus*, from ilium to ribs ; *erector spinæ*, from ilium to vertebræ, and the *psoas parvus*, from pubes to bodies of vertebræ.

Speaking of the limbs more particularly, the following are the *pre-axial* muscles of the upper limb. *Latissimus dorsi*, from lumbar and dorsal spines to groove at upper part of humerus ; *deltoid*, from scapula and clavicle to outer part of humerus ; *supraspinatus*, from upper part of scapula to greater tuberosity of humerus ; *infraspinatus* and *teres minor*, from lower part of scapula to greater tuberosity ; *triceps extensor cubiti*, from scapula and humerus to upper part of ulna ; and beyond this, the *supinators* and *extensors* of the forearm and hand. The following are the *post-axial* muscles of upper limb : *pectoralis major*, from clavicle and sternum to the upper part of humerus below lesser tuberosity; *coraco-brachialis*, from the coracoid bone or process to the inner surface of shaft of humerus ; *biceps flexor cubiti*, from upper part of glenoid cavity and coracoid process to the tuberosity of the radius; *brachialis anticus*, from the front of humerus to the upper part of ulna ; and below this the *pronator* and *flexor muscles* of the forearm and hand.

Lower Limb.—Pre-axial Muscles: glutæus maximus, from ilium and sacrum to the outer and back part of femur ; *tensor vaginæ femoris*, from the ilium to the outer part of fascia lata of thigh and to the fibula ; *quadriceps extensor cruris*, from the ilium and femur to the patella and tibia ; to these succeed the *extensors* of the leg and foot. *Post-axial muscles : pectineus*, from the pubes to the inner part of femur ; *adductors*, from the pubes to the femur ; *obturators*, from the ilium to the upper part of femur ; the *biceps*, *semi-membranosus*, and *semi-tendinosus*, from the tuberosity of the ischium to the back part of tibia, and fibula ; the *poplitæus*, from outer condyle of femur to back of tibia, and the *flexor* muscles of the leg and foot.

Homologies of these Muscles.—The homologies of the muscles of the upper and lower limbs is a difficult subject, and one which has of late received much attention. The following are the most important facts which have been made out as to the homologous muscles of the two limbs :

Latissimus dorsi of arm	is homologous to	*Glutæus maximus* of leg
Pectoralis major	„ „	*Pectineus*
		(*Psoas magnus*, *Pyriformi*, and *Femoro-coccygeus* are without homologues)
Deltoid	„ „	*Tensor vaginæ femoris* of leg
Supra-spinatus	„ „	*Iliacus*
Infra-spinatus, and *Teres*	„	*Glutæus medius et minimus*
(*Subscapularis* has no homologue)		
Triceps and *Supinator brevis* of arm	are homologous to	*Quadriceps extensor* of leg
Biceps of arm	is homologous to	*Sartorius* and *Gracilis*
Supinator longus of arm	is homologous to	*Semimembranosus* and *Semitendinosus*
Brachialis anticus	„ „	Short head of *Biceps cruris*
Pronator radii teres	„ „	*Popliteus*
Extensor communis digitorum	„	*Extensor longus digitorum*
Extensor carpi ulnaris	„	*Peroneus tertius*
Flexor longus pollicis	„ „	*Flexor longus hallucis.*
Flexor profundus digitorum	„	*Flexor longus digitorum*
Palmaris longus	„ „	*Plantaris*
Flexor carpi radialis	„ „	*Tibialis posticus*
Flexor sublimus digitorum	„	*Gastrocnemius* and *Soleus*

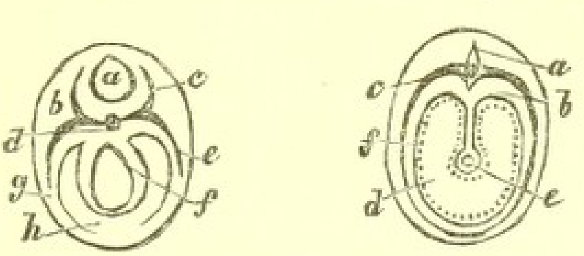
Development of Vertebræ.—At a very early period the embryo is composed of three layers, an upper *epidermic*, an inner *mucous*, and a middle *serous* coat; from the upper are developed the medullary portions of the brain and spinal cord and the integument of the body; from the inner layer the alimentary canal and its dependencies are formed; and from the middle are developed the skeleton, the muscular and vascular systems, and many other parts of the body.

The upper part of the middle and contiguous upper layer very early presents a median longitudinal depression, the *primitive vertebral groove*; from each side of which a fold passes upwards, converging towards its fellow, which it finally meets, so as to enclose a canal, at the bottom of which the *chorda dorsalis*, or notochord, is laid down. The folds are called the *laminæ dorsales*, and the tube the *neural canal.* Two folds similar to these laminæ dorsales pass downwards, and finally unite to enclose a much larger tube than the neural canal; this tube encloses the *alimentary canal*, which indeed is formed by a splitting of the *laminæ ventrales*, as the two inferior folds are called.

The *notochord* and the inner part of the *laminæ dorsales* next become studded with little blocks of cartilage, which appear first at the cephalic end, and from which the future vertebræ are formed; these cartilaginous blocks are called *primitive* or *primordial vertebræ*, and from them are developed the ribs where they exist, and throughout their whole extent the central part of a pair of spinal nerves and the contiguous spinal muscles, as well as the greater part of the vertebræ themselves.

Finally, the notochord is converted into bone, forming the bodies of the vertebræ, except where it persists as the pulp in the interior of the intervertebral fibro-cartilages which is interposed buffer-like between the bodies of contiguous vertebræ. The transverse processes and articular processes arise by separate centres of ossification, as does also the odontoid process, which is, as before stated, really the separated body of the atlas. During development a series, generally four in number,

Fig. 43.



(*From Mivart.*)

1. Diagram of the development of the trunk and its skeleton, as shown in a section made at right angles to the trunk's long axis. *a.* Neural canal. *c.* Epaxial cartilages rising up to form the primitive vertebral groove and finally surrounding the neural canal. *e.* Paraxial cartilages descending in the plate or layer *g*, external to *h*, the pleuro-peritoneal cavity. *f.* Internal plate of the split ventral laminæ. 2. Diagram of the further development of the trunk, as shown in a section similar to the last. *a.* Epaxial arch. *b.* Hypaxial arch, descending in the median line in the root of the inner part of the split wall of the ventral laminæ. *c.* Rib bifurcating proximally and abutting ventrally against the sternum, which thus completes the paraxial arch. *d.* The pleuro-peritoneal space. *e.* Alimentary canal, supported by a mesentery formed by the dorsal portion of the inner parts of the split walls of the embryonic ventral laminæ.

of so-called *visceral arches* appear, parallel and posterior to the mouth, the spaces between which deepening into profound grooves from the visceral clefts, serve to establish a free communication between the pharynx and the external medium. Their further development varies in the different vertebrate classes.

Reproduction of Vertebrata.—The reproduction and development of Vertebrata are described in Chapters XXXV., XXXVI., and XXXVII.

CHAPTER XXIII.

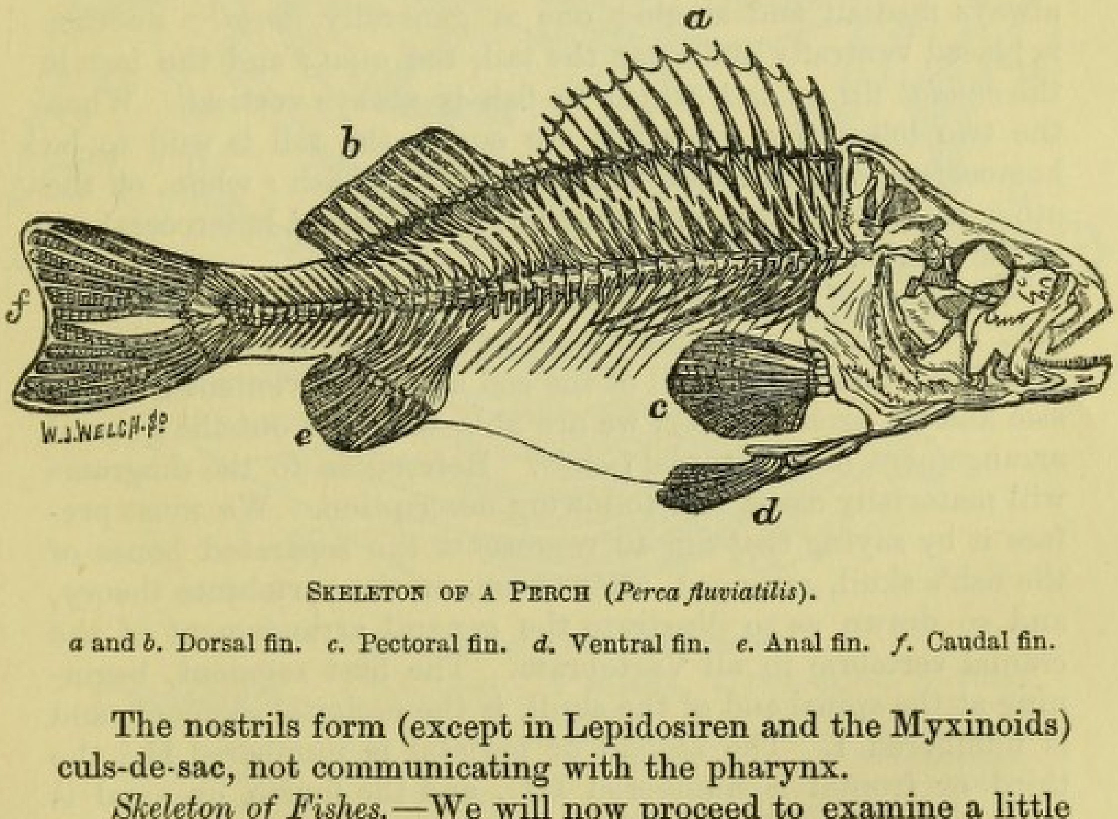
General Characters of Pisces—Skeleton—Scales of Fish.

Class I. PISCES.

Definition.—Pisces live in water, and breathe by means of gills. The heart consists of two cavities only, and is respiratory in character. An auricle receives the impure blood of the body and propels it into the ventricle, whence it is pumped, through a vessel which divides into four or five branches, to the gills; here it is purified by being brought into contact with the oxygen dissolved in, but not chemically combined with, the water, and being re-collected by the branchial veins, it is poured by their convergence into a large vessel which runs along the dorsal aspect of the alimentary canal, and corresponds to the aorta; by this it is transmitted to the entire body, except the gills. The body is generally covered with scales. The limbs are modified into fins. The primordial renal organs, corpora Wolffiana, persist through life. The kidneys are not divisible into cortical and medullary portions, but consist of cortical substance only; the ureters open into a cloaca common to themselves and the rectum. The kidneys receive a supply of venous blood, just as the liver does. The cerebral part of the nervous system is but slightly developed, and affords a clue to the plan of construction of the vertebrate brain. It is arranged as an antero-posterior chain of ganglia, called from before backwards, *rhinencephalon*, *prosencephalon*, *mesencephalon*, and *epencephalon*. We are able to discover, from the simple character of fishes' brains, the true arrangement of the elements of the brains of all vertebrate animals, whose brains differ from each other solely by the greater comparative development of one or another of their cerebral ganglia. The first pair of ganglia compose the *olfactory lobes*, the second constitute the *cerebral hemispheres* (or their earliest and most constant elements, the *corpora striata*), the third are the *optic lobes*, and the fourth compose the bilaterally symmetrical *medulla oblongata*, upon which rests a single lobe, the representative of the *cerebellum*. No external organ of hearing or tympanum exists, but a vestibule and semicircular canals are present. A lymphatic and lacteal system exists in all fishes except Amphioxus. The lymphatics are not very numerous, but contractile dilatations exist in connection with the jugular vein in many fishes, which are termed 'lymphatic hearts.'

Besides the modified limbs which form the pectoral and ventral fins, and which are always double, there are median single fins, forming the dorsal and anal fins, and which are probably developed from the exo-skeleton. They always consist of two sets of bones, *interspinous bones,* which articulate with the neural and hæmal spines, and *fin rays,* which are connected with the extremities of the former.

Fig. 44.



SKELETON OF A PERCH (*Perca fluviatilis*).

a and *b*. Dorsal fin. *c*. Pectoral fin. *d*. Ventral fin. *e*. Anal fin. *f*. Caudal fin.

The nostrils form (except in Lepidosiren and the Myxinoids) culs-de-sac, not communicating with the pharynx.

Skeleton of Fishes.—We will now proceed to examine a little in detail the skeleton of Pisces.

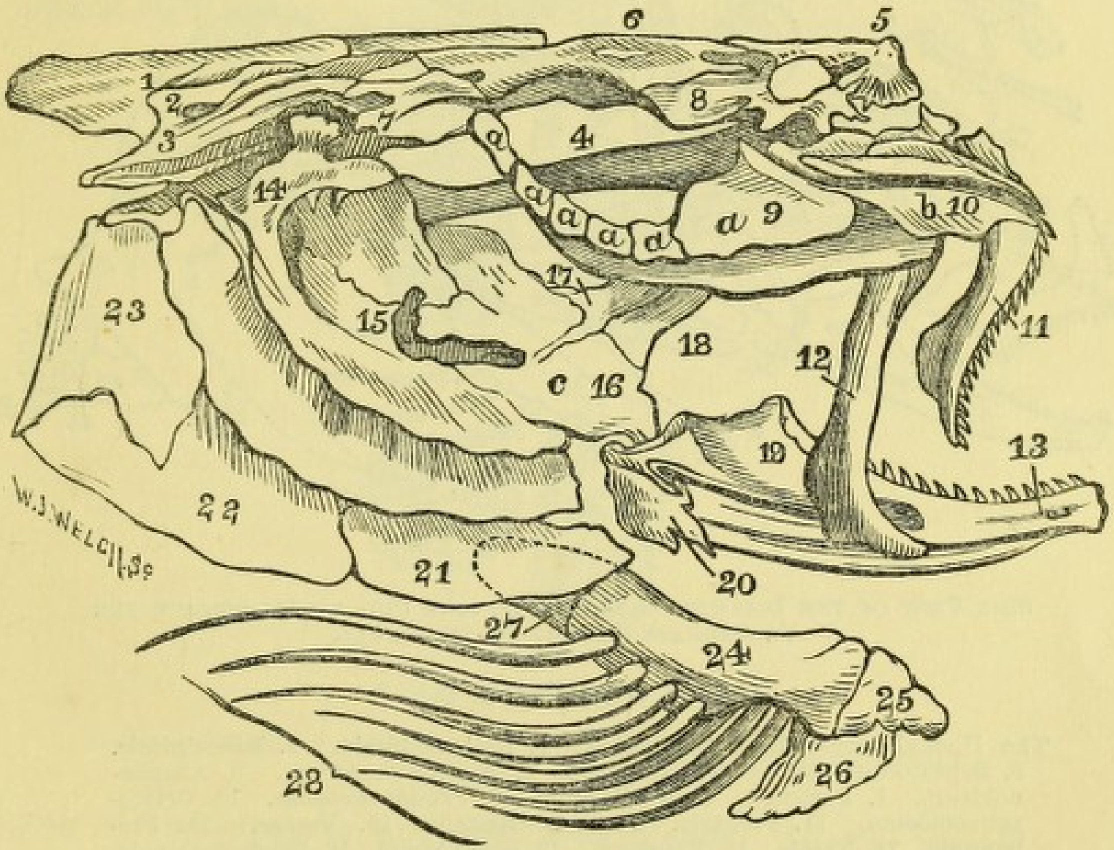
In the Lancelet there is no vertebral column, but the tapering cylindrical cellular rod, the notochord, is persistent throughout the life of the animal. Many fishes possess a skeleton entirely composed of cartilage, others one in which cartilage is blended with bone, and others again possess a complete osseous skeleton.

Vertebral Column.—The trunk vertebræ are only divisible into dorsal and caudal vertebræ. The body of each vertebra is cupped both in front and behind (amphicœlous) except in the bony pike, in which fish the anterior part of each vertebra is globular, and is received into a socket on the posterior aspect of the succeeding vertebra, to which state of things the term *opisthocœlous* is applied. The spine possesses a neural arch throughout its length which lodges the cord, and a hæmal arch at its tail end for the protection of the principal blood-vessel or aorta. There is no sternum, the ribs being plunged among the lateral muscles. Connected by ligaments to the neural spines are a series of dagger-shaped bones, 'the handles towards the hand,' when raising a fish by the dorsal fin, connected with, or developed from, the integumental system, hence belonging to the exoskeleton, and called the *interspinous* bones. These bones support the median dorsal fins by the so-called *fin rays*, which latter are either single hard bones, or many soft slender pieces joined together. The fins which these bones support are always median and single ; one is generally *dorsal* ; another is placed ventrally and near the tail, the *anal* ; and the last is the *caudal* fin or tail, which in fish is always vertical. When the two lobes of a fish's tail are equal, the tail is said to be homocercal, as is the case in the majority of fish ; when, on the other hand, the lobes are unequal, it is termed heterocecal, as in the sharks.

The *skull* of fishes is at first sight a very complex mechanism, but, if carefully examined, the difficulty in a great measure vanishes ; taking the skull of the cod as one convenient from its size and its procurability, we are able to make out the general arrangement of the cranial bones. References to the diagrams will materially assist the following description. We must preface it by saying that fig. 46 represents the separated bones of the fish's skull, arranged, after Owen, on the vertebrate theory, and so drawn as to illustrate the general arrangement of the cranial vertebræ in all Vertebrata. The first segment, beginning at the spinal end of the skull, is the occipital segment, and is numbered I. The second or parietal is numbered II., the third or frontal is numbered III., and the fourth or nasal is numbered IV. The neural segments are slightly shaded, the hæmal arches are in outline. The sense capsules of the eye and ear are intercalated respectively between the third and fourth, and the first and second cranial vertebræ. A similar preparation of the bones of a cod's skull can be made by slightly boiling a suitable specimen and then macerating it in water which is to be frequently changed ; the skull in the meantime being suspended in a muslin bag to prevent any of the small bones being lost or mislaid. The articulation of such a specimen would well repay the time and trouble it takes.

Appendicular Skeleton.—The full complement of four limbs are not always present, but when present they form the pectoral and ventral fins. The *pectoral fins*, or fore limbs, are appended to the occipital bone by the scapular arch, which has been already described. The fin generally presents a short, strong humerus, to which two parallel bones succeed, homologues of

Fig. 45.



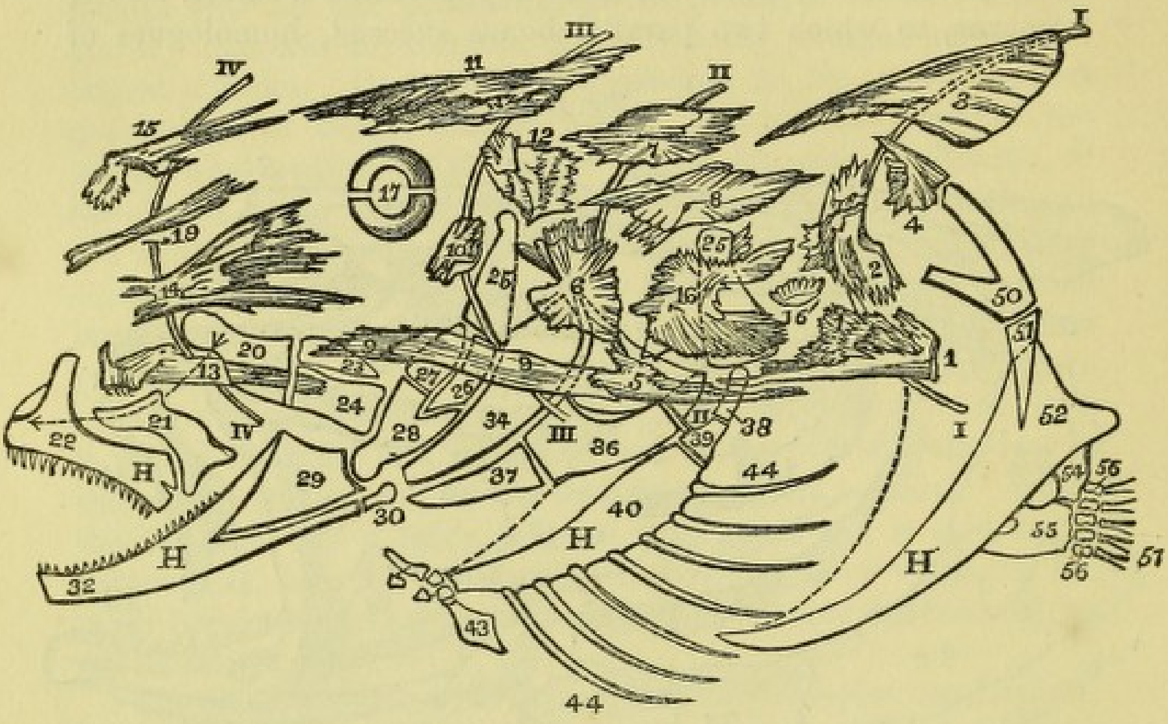
SKULL OF COD (*Morrhua vulgaris.*)

1. Supra-occipital. 2. Paroccipital. 3. Mastoid. 4. Presphenoid. 5. Nasal. 6. Frontal. 7. Postfrontal. 8. Prefrontal. 9. Lachrymal. 10. Dermic bone, the Supra-temporal. 11. Premaxillary. 12. Maxillary. 13. Dentary. 14. Tympanic. 15. Preopercular. 16. Dermic bone. 17. Entopterygoid. 18. Pterygoid. 19. Articular. 20. Angular piece. 21. Interopercular. 22. Subopercular. 23. Opercular. 24. Ceratohyal. 25. Basihyal. 26. Urohyal. 27. Epihyal. 28. Branchiostegal rays. *a*, *b*, and *c* are dermic bones.

the radius and ulna, which are succeeded by a great many small ossicles, the representatives of the carpus in higher animals, and in fishes bearing the fin rays, which may be looked upon as made up of metacarpals and phalanges.

The *pelvic arch* is sometimes placed close beneath the pectoral fins, when it is attached to the coracoid bone, as in the perch ; in this case the ventral fin is said to be jugular or thoracic in position. When the fin is placed at the hinder part of the body, it is said to be abdominal. The pelvic arch is often entirely absent, but when present it consists of two strong bones, the ischia, which are suspended among the muscles of the trunk ;

Fig. 46.



SIDE VIEW OF THE DISARTICULATED SKULL OF A COD, TO ILLUSTRATE THE VERTEBRATE THEORY OF THE SKULL.

(*From Owen.*)

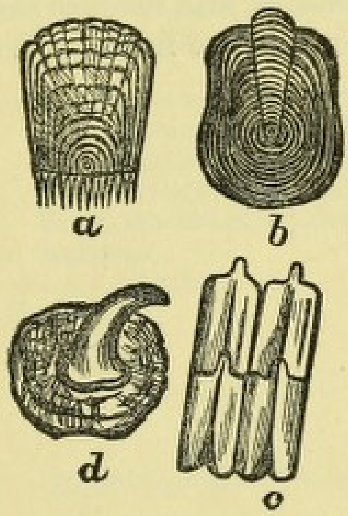
The Hæmal arches H H in outline. 1. Basi-occipitale. 2. Exoccipitale. 3. Supra-occipitale. 4. Paroccipitale. 5. Basi-sphenoideum. 6. Alisphenoideum. 7. Parietale. 8. Mastoideum. 9. Presphenoideum. 10. Orbitosphenoideum. 11. Frontale. 12. Post-frontale. 13. Vomer. 14. Prefrontale. 15. Nasale. 16. Petrosum. 17. Scleroticum. 18. Ethmoturbinale. 19. Turbinale. 20. Palatinum. 21. Maxillary. 22. Premaxillary. 23. Entopterygoideum. 24. Pterygoideum. 25. Ectopterygoideum. 26. Malar. 27. Squamosum. 28. Tympanicum. 29. Articulare. 30. Angulare. 31. Splenium. 32. Dentarium. 29 to 32. Mandibulare. 34. Preoperculum. 35. Operculum. 36. Suboperculum. 37. Interoperculum. 38. Stylohyale. 39. Epihyale. 40. Ceratohyale. 41. Basi-hyale. 42. Glossohyale. 43. Urohyale. 44. Branchiostegum. 46. Thyrohyale. 50. Suprascapula. 51. Scapula. 52. Coracoideum. 53. Humerus. 54. Ulna. 55. Radius. 56. Carpus. 57. Metacarpus. 58. Clavicula.

to these ischia the fin rays are directly appended without the intervention of any representatives of the thigh or leg bones.

The exoskeleton of fishes is composed of scales.

Scales of Fishes.—The scales of fish differ from other integumental growths in being dermic rather than epidermic productions. Nails, hair, teeth, and feathers are developed from the upper layer of the derm, but scales are developed within the substance of the derm itself. Each scale consists of three layers, (1) an outer layer of homogeneous plates, which are generally arranged circularly with the smaller ones at the apex, and the larger at the base ; (2) a middle calcareous layer, containing all the dense parts of the scale ; (3) an inner fibrous layer, the fibres being arranged at various angles to each other. In the ganoid scales we find a structure like true bone forming the basis of the scale, and this is coated with the glistening *ganoin*. A series of canals run through the scales both longitudinally and at right angles to each other : these tubes answer the pur-

Fig. 47.



VARIETIES OF FISH SCALES.

a. Ctenoid scale. *b.* Cycloid scale. *c.* Ganoid scale. *d.* Placoid scale.

pose of sudoriparous and sebaceous glands. In the placoid scales a series of dermic teeth are commonly found, which on section closely correspond to the structure of dentine in true teeth.

There are four principal varieties of fishes' scales—1. Cycloid, 2, Ctenoid, 3. Ganoid, and 4. Placoid.

1. Cycloid (κύκλος, a circle) scales are the most frequently met with of any kind. They are circular or elliptical in shape, generally of a silvery lustre, and are thin and flexible. The perch is an example of a fish possessing cycloid scales.

2. Ctenoid (κτείς, a comb) scales are thin and flexible scales, generally less glistening than cycloid scales, and having their posterior margins furnished with a comb-like fringe of toothed processes. The sole possesses ctenoid scales.

3. Ganoid (γάνος, brightness) scales are generally larger than

the preceding, and consist of an under dermic layer of bone, and a superficial enamel-like coating, which constitutes the so-called 'ganoin.' Most ganoid fishes are extinct, but the Lepidosteus is an example of a fish still possessing such scales.

4. Placoid (πλάξ, a flat plate) scales are formed of bony granules, or tubercles, or plates, the plates being often furnished with spines. The shark tribe possess placoid scales.

In addition to these scales most fish possess a series of small scales running along the side of the body, and called the 'lateral line.' Each scale is perforated in its centre by a tube, which is connected with a subdermic longitudinal tube, which runs along the whole length of the body, and is connected with cavities in the head. This system is concerned in secreting the mucus which lubricates the scales, and enables the fish to move through the water with little resistance from friction.

CHAPTER XXIV.

ORDERS OF PISCES.

FISHES contain the following orders :—

Order 1. Pharyngobranchii (Cirrostomi—Leptocardia), *e.g.* Amphioxus.
„ 2. Marsipobranchii (Cyclostomata), *e.g.* Lamprey.
„ 3. Teleostei.
Sub-Order A. Malacopteri (Physostomata), Salmon.
„ B. Anacanthani, Turbot.
„ C. Acanthopteri, Wrasse.
„ D. Plectognathi, Trunk Fish.
„ E. Lophobranchii, Sea Horses.
„ 4. Ganoidei, *e.g.* Sturgeon.
„ 5. Elasmobranchii, *e.g.* Sharks.
„ 6. Dipnoi, *e.g.* Mud Fish.

Another classification of fish is the following :—

Orders		*Type*
1. Leptocardii .	Branchiostomi—Cirrhostomi	Lancelet
2. Cyclostomi .	Dermopteri . . .	Myxine Lamprey
	Sub-Orders	
3. Teleostei	1. Physostomi	Eel
	2. Anacanthani . . .	Cod
	3. Pharyngognathi . .	Flying Fish Wrasse
	4. Acanthopteri . .	Perch Mullet
	5. Lophobranchii . . .	Pipe Fish
	6. Plectognathi . . .	Sun Fish
4. Ganoidei	1. Holostei	Bony Pike
	2. Chondrostei	Sturgeon
5. Selachii	1. Holocephali	Chimæra
	2. Plagiostomi . . .	Sharks Rays

We shall, however, adopt the first classification in describing the various piscine orders.

Order 1. **Pharyngobranchii** (φάρυγξ, βράγχια, the gills) contain but one member, the Lancelet, *Amphioxus lanceolatus.*

The Lancelet is a little fish of the size of a minnow, which burrows in the mud of the Mediterranean Sea. It presents the following characters :—The notochord is persistent, and runs from one end of the animal to the other. Most of the characters of this curious and anomalous animal are, however, negative ; thus no vertebral column is ever developed, nor any cranium, or brain, or heart, or auditory organs, or kidneys, or external limbs of any kind. The mouth is a longitudinal fissure, surrounded with fringed cirri, and unfurnished with a mandible. The blood is pale, *not red*, and is propelled through the vessels by a power of contraction residing in their walls. The pharynx is perforated (which circumstance has given origin to the name of the order) by several ciliated apertures, which serve as gills, and so act as respiratory organs ; for this same reason the order is sometimes called 'Branchiostoma.' The water, containing admixed oxygen, which is admitted to purify the blood is expelled by an abdominal pore close to the anus. Through this pore, too, the spermatozoa and ova both escape.

Order 2. **Marsipobranchii** (*μάρσιπος*, a pouch ; and *βράγχια*) comprise the Lampreys and Hags. The skeleton is chiefly cartilaginous ; the notochord persists ; branchiæ non-ciliated and sac-like. A heart exists, but there is no *bulbus arteriosus* ; a median fin is situated at the hinder part of the body, which runs round from the dorsal to the ventral aspect.

The form of the fish is round and eel-like. The mouth of the Marsipobranchii is sucker-like ; there are no lips, but the tongue, acting after the fashion of a piston, produces a vacuum which, the contraction of the mouth relaxing, becomes filled with fluid nutriment. The Hags (Myxinidæ) have in addition a single large recurved serrated fang, situated on the roof of the mouth. This tooth is freely movable, and worked by the powerful muscles of the mouth ; it enables the fierce Hag-fish to penetrate the bodies of animals on which it preys. The mouth is surrounded with cirri. In the Lampreys numerous teeth are developed upon the palate, lips, and tongue ; the nasal passages end in culs-de-sac, as in other fish ; but in the Hag-fish the nasal sacs communicate by one aperture with the mouth, and by another, called the 'spiracle,' or 'blow-hole,' with the top of the head.

Respiration is effected by an arrangement of plicated and highly muscular little membranous pouches, or marsupia, (hence the name of the order), which are placed linearly one behind another along the sides of the neck ; these sacs open into a dilated tube which joins the pharynx. There is no gill-cover, but little circular foramina run from the exterior to the gill sacs : the Lampreys have six or seven of these communicating apertures ; the Hags only possess one. These serve as auxiliary mouths, for when one of these creatures has fixed itself to any object by the suctorial power of its mouth, it would be impossible for it to inhale water in the ordinary manner, and therefore they are provided with these lateral slits in addition. There is no swim-bladder.

Order 3. **Teleostei** (τέλειος, perfect ; ὀστέον, a bone) comprise all the true osseous fishes, and is consequently very much the largest and most important of all the Piscine orders.

The vertebral column, except in Plectognathi and Lophobranchii, consists of perfectly ossified segments; the mandible and skull too are completely osseous. Both pectoral and ventral fins are not invariably present ; but when they are, the pectoral limbs are always provided with clavicles. The gills are hidden by a gill cover, and are *pectinated* or *tufted.* Branchiostegal rays are developed. Bulbus arteriosus always present. The fins when present are sometimes supported by numerous soft rays (Malacopteri) or with dense single rays (Acantheropteri). The tail is always homocercal. The exoskeleton of Teleostei varies widely ; as a rule it is formed of cycloid or of ctenoid scales ; but it may be quite absent, or it may, as in *Ostracion*, form a complete unyielding coat of mail, or it may be, as in *Balista*, beset with spines.

Teleostei generally possess teeth, which as a rule are implanted in the bones of the skull, but only rarely planted in sockets ; they, as a rule, consist of dentine covered with irregular plates of enamel. The teeth are numerous and scattered over many of the oral and cranial bones in some fish, as *e.g.* in the Carp, extending as far back as the basi-occipital bone.

Some of the Teleostei, as *e.g.* the Climbing Perch (*Anabas*), the *Saccobranchus singio, Amphipnous cuchia* and *Heterotis*, possess the power of sustaining life for a long time when removed from the water; this is due to their possession of accessory respiratory organs, in the shape of tufted vascular processes, something like external gills, or in saccular cæcal prolongations of the branchial cavity. The Blind Fish (*Amblyopsis spelæus*) of the Kentucky caves, does not possess any real organs of vision ; but a lens, choroid, choroidal gland, and cornea are present. Some of the Teleostei, *e.g.* the very curious Pipe-fish *Syngnathus*, and other *Lophobranchii*, develop integumental ventral pouches or marsupia, which serve to lodge the young, and, according to some, even to nourish them, by a secretion poured out from the marsupial glands.

Sub-order A. MALACOPTERI (μάλακος,soft ; πτερόν, a wing) (Physostomata). *Osseous fishes with soft many-jointed fin-rays, and a swimming-bladder which is furnished with a pneumatic duct.*

Scales generally cycloid, rarely ganoid. They comprise the Apoda, and the Abdominalia, the former being destitute of ventral fins, the latter possessing them. To the former group belong the Eels ; to the latter, Herrings, Pike, Carp, Roach, Dace, Barbel, Chub, Minnows, Salmon, Trout, and Sheat-fish.

The *Apoda*, Eels (*Murænidæ*), are supplied with a small pair of pectoral fins, but there are no ventral fins. They are cylindrical, and even worm-like, in shape, and are enveloped in a tough hide furnished with minute deeply-sunk cycloid scales. The gill-cover is hidden by the skin. To this group also belongs the Gymnotus, the formidable electric eel of South America ; nearly the entire body of this animal, often six feet in length, is occupied by the electric organ, all the other organs being packed together into a very little compass close to the head. A single discharge of electricity from this gigantic battery is sufficient to kill a horse. The *Abdominalia* comprise the greater number of living fishes : in all the skeleton is completely ossified, and the vertebræ are always amphicœlous. An electrical fish, the *Malapterurus* of the Nile, is likewise found in this group. The *Siluridæ*, or Sheat-fishes are included in this division ; they are remarkable for possessing certain hollow spines, forming formidable weapons of offence, and developed from the first ray of the pectoral fin. They are called ' ichthyodorulites,' and can be raised or depressed at will. Many fossil fish possessed these appendages, but the Siluroids are the only living fish in whom they are met with.

Sub-order B. ANACANTHANI (ἀνά, without ; ἄκανθα, a thorn). *Osseous fishes with soft fin-rays, a swimming bladder devoid of a pneumatic duct, and ventral fins either absent or jugular in position.* There are two sub-divisions, much as in the last sub-order, and called Apoda and Sub-Brachiata.

Apoda. No ventral fins. Comprise the little Sand-lance (Ammodytes).

Sub-Brachiata. Ventral fins present. This large group includes the Cod Family, and the *Pleuronectidæ*, flat fishes, such as Sole, Turbot, Halibut, Plaice, &c. The flat fishes owe their singular shape to the enormous length of the interspinous bones, which project vertically from the hæmal and neural spines. They have no swimming-bladder, and lie at the bottom of seas and rivers. They lie on their side, so that the surfaces are right and left, not dorsal and ventral. The eyes are both placed on the upper surface, and the whole parts of the cranium strangely distorted to keep both mouth and eyes out of the mud. No creatures possess more typical examples of asymmetrical crania than the Pleuronectidæ, an asymmetry which seems largely due to their habits, as the eyes and mouth at birth are symmetrical, occupying both sides of the head, and only assume their ultimate position after a period of time, during which the eyes and mouth gradually work over. The side on which the flat fish lies is generally white, the upper surface generally brown.

Sub-order C. Acanthopteri (ἄκανθα, a thorn ; πτερόν, a wing). *Osseous fishes with unjointed spiny rays.* Scales, generally ctenoid. Swimming-bladder has no pneumatic duct. Ventral fins when present generally jugular in position. This large group comprises the Perch, Mullet, Mackerel, Gurnard, Goby, Blenny, Angler, and Wrasse.

Sub-order D. Plectognathi (πλάξ, a flat plate ; γνάθος, a jaw). Comprise the Trunk fishes or *Ostraciontidæ. The endoskeleton is not thoroughly ossified in this aberrant group, but the exoskeleton is developed into a very singular and complete investment of dense ganoid armour plates.* The maxillæ and premaxillæ are anchylosed together. The File-fishes (Balistidæ) and Globe-fishes (Gymnodontidæ) also belong to this group.

Sub-order E. Lophobranchii (λόφος, a plume, βράγχια). Sea Horses, *Hippocampi*, and Pipe Fishes, *Syngnathidæ. Branchiæ arranged in plumes or tufts upon the branchial arches.* Endoskeleton not completely ossified—exoskeleton of ganoid plates. No pneumatic duct to swim-bladder. The marsupium or pouch before referred to as being developed from the integument of the Hippocampi is possessed by the male fish alone, who is in very deed a mother to his offspring.

Order 4. **Ganoidei.** Embrace Sturgeons, Bony Pike, Polypterus, and many extinct forms. The vertebral column is rarely completely or even considerably ossified, except in one remarkable exception, that of the Lepidosteus or Bony Pike of the Mississippi, in which animal the contiguous vertebræ are fitted into each other by true ball and socket joints (opisthocœlian vertebræ), and the entire column is completely ossified ; no other fish indeed has so firm a vertebral column as the Lepidosteus.

The exoskeleton is always composed of ganoid plates or scales. These plates, as a rule, are accurately fitted to each other, like mosaic tiles, forming a continuous coat of mail : occasionally, however, they are imbricated. The Ganoidei do not, it must be remembered, comprise all the fish with ganoid scales, several of such fish being met with among the Teleostei. Pectoral and ventral fins generally present : the ventral being abdominal in position. Tail either homocercal or heterocercal. Branchiæ beneath gill-cover also protected by branchiostegal rays and branchiostegal membrane. Swim-bladder, with pneumatic duct, always present. Bulbus arteriosus separated from ventricle by several rows of valves. Intestine often possesses a spiral fold, formed by a reduplication of the lining membrane.

The *Lepidosteus* inhabits the lakes of N. America, the *Polyterus* the waters of the Nile : each is a ganoid of from 18 inches to 4 feet in length. The *Amiæ* are like Trout in form, and inhabit the fresh waters of N. America. The *Sturgeons* (Sturionidæ) lie at the bottom of muddy rivers in Europe and live by suction. They have an imperfect cartilaginous skeleton, but a strong exoskeleton of ganoid plates which protects the head and a good portion of the body. Tail heterocercal. Notochord in a great degree persistent through life. Neural arches cartilaginous ; no teeth ; the muscular snout hanging from the mandible sucks up nourishment from the bottom of the streams in which they lie. Some attain a great size, *e.g.*, the Beluga grows to twelve feet and upwards. The roe of the Sturgeon is the caviare of commerce. A great number of extinct fish are relegated to this order, all being characterised by the possession of a large head and a tapering body, the head alone being protected by ganoid plates. Examples, *Pterichthys*, *Pteraspis*, *Cephalaspis*, *Coccosteus*.

Order 5. **Elasmobranchii** (ἔλασμα, a thin plate ; βράγχια). Sharks, Rays, and Chimeræ. Branchiæ lateral and formed of thin plates or laminæ, arranged like the leaves of a book, opening externally to the water, internally to pharynx. No gill cover, or branchiostegal rays. Skull entirely cartilaginous. Vertebral column osseous, or cartilaginous, or sub-notochordal. Exoskeleton of placoid granules and plates. Both pairs of fins present, and ventral fins placed near the anus. There is no clavicle. Bulbus arteriosus provided with two, three, or more rows of valves. Intestine provided with a spiral fold of mucous membrane which winds screw-like round the intestine from stomach to vent, and of course much increases its absorbing surface. Sometimes, as in the Chimeræ (*Holocephali*), the mouth is terminal ; more frequently, as in the Sharks and Rays (*Plagiostomi*), it is placed, like a pig's, on the under surface of the head, and opens by a great transverse gap.

The *Chimæra monstrosa*, king of the herrings, is the best known living example of the Holocephalous division. Only one gill slit is visible from without, but there are really five gills present. Notochord persistent. 'Ichthyodorulites' on pectoral fins. Tail heterocercal. Partially developed branchiostegal rays and membrane.

The *Plagiostomi* comprise the Sharks and Rays. The gills communicate by five openings with the exterior and interior. No gill cover. Skull a single cartilaginous bone. Mouth transverse often armed with rows of recurved teeth, which are so attached to the mandible and adjoining oral structures by ligament as to permit them to be pressed backwards by any entering guest, but the pressure once removed, the dental portcullis springs erect again and prevents the exit of anything or anyone who may have entered the capacious and powerful maw. In the *Cestraphori*, in which division we find the Port Jackson Shark, there is a strong spine upon the joints of each dorsal fin, and the teeth are flat, very numerous and tessellated like a mosaic pavement. Most Cestraphori are extinct. The *Selachii* comprise the largest and fiercest of the fish class; the White Shark, *e.g.*, attains a length of thirty feet, and is the most voracious of living creatures. The gills of Selachii are lateral, and the ventral fins anal. The teeth form numerous rows; they are flat, triangular, and often serrated at their edges. In the *Batides*, the Rays and Skates, the gills are on the under-surface. The pectoral fins, especially the terminal rays, the homologues of the phalanges, are enormously elongated, and, being covered by muscles and a scaly derm, form the greater part of the entire animal. The Rays by this expansion of the pectoral fins become flat fish, but, unlike the Pleuronectidæ, the surfaces are dorsal and ventral, and not right and left. The Torpedo belongs to the family of Batidæ. In the Saw-fish, *Pristis antiquorum*, the premaxillæ, studded laterally with straight, strong, sharp teeth, are elongated to a length of several feet, and constitute a very formidable weapon of offence.

Most of the Elasmobranchii produce very few eggs; these are, however, very carefully protected by tough leathery egg-cases—and so the perpetuation of the race is sufficiently secured. These egg-cases, or 'sailors' purses' as they are commonly called, abound on most of our coasts, the tendril-like filaments which proceed from each of the four corners serve to moor them to sea-tangle or sea-weed, where they ride safely at anchor until the young ray, or skate, is hatched and escapes.

Order 6. **Dipnoi** (δίς, twice; πνοή, breath) comprise the Protopteri, or Mud-fishes, and form the true connecting link between Pisces and Amphibia. The *Lepidosiren annectens* is the best known member of this order. The notochord is persistent, but the cranium and mandible are well developed. Scales cycloid. Both pairs of limbs present. Pectoral fins connected with the occiput, the ventral fins placed near the tail: the fins are small round-jointed filiform organs, not in the least resembling ordinary fins. There is a median dorsal fin in the form of a thin transparent membrane which extends round on to the ventral aspect. The vertebræ are ossified and about forty in number. There are rudimentary external branchiæ and internal gills which communicate with the exterior by a single gill slit. They also possess true lungs, their first appearance on the stage of life, which are clearly modifications of the swim-bladder, and which communicate with the gullet by a tube or trachea. The nasal fossæ are blind sacs, an eminently piscine characteristic. Clavicles present. Heart tricœlian; two auricles and one ventricle. During the long droughts common in Africa the Lepidosiren often remains high and dry out of the water, and then is enabled to live a true aërial existence by means of its lungs, returning to the water on the advent of the wet season, when the pulmonary function is again abrogated, and the animal breathes by means of its branchiæ.

Dr. Günther considers that Dipnoi form a group of Ganoidei, and unites Ganoidei and Elasmobranchii into one order, Palæichthyes, characterised by possessing a contractile bulbus arteriosus, an intestine with a spiral valve, and optic nerves which do not decussate.

CHAPTER XXV.

Physiology of Pisces.

Digestion.—The jaws are the only organs of prehension which a fish possesses. To render them as efficient as possible, both jaws are movable, and capable of protrusion and retraction, as well as of opening and shutting. The teeth of fishes are almost infinitely various in number and shape. The Myxine or Hag-fish has but one tooth, with which it eats its way into the vitals of its victims. The Pipe-fish, the Sturgeon, and others, are quite toothless. The Tench has powerful pharyngeal teeth, *i.e.* situated in and about the pharynx, and one tooth on the occipital bone. In the Shark family they are exceedingly numerous, row behind row, and are still more numerous in the Pike tribe. The teeth are placed on most of the bones about the head, often studding not only the premaxillary and dentary bones, but the vomer, the basi-occipital and basi-sphenoid, the hyoidean arches, the super-maxilla, the pharynx, pterygoid, sphenoid, nasal bones, and branchial arches. They are very generally anchylosed to the bone, but in some fishes, as in the Lophius, and some Sharks, they are attached by means of elastic ligaments, which will allow them to be bent backwards towards the gullet, but the pressure being removed enables them to spring into position again. In structure they are often composed of dentine only; but in the Diodons, and some Sharks, teeth are met with composed of enamel, cement, dentine, and osteo-dentine. In shape they are most often conical, sometimes lancet-shaped, as in the Barracuda; sometimes flattened at the top and arranged like a mosaic pavement, as in the Port Jackson Shark; sometimes notched at the sides, as in the majority of the Shark family; sometimes cuneiform, as in the Parrot-Fish.

A pharynx, as has already been intimated, is peculiar to the Vertebrata, and is therefore first met with in fishes. In this class it is short, does not communicate with the nasal passages, and leads into a short œsophagus. The œsophagus leads into a true digestive stomach, which is sometimes guarded by a cardiac as well as by a pyloric valve. The intestine is wide and short, the difference between large and small being only indicated by a slight constriction ; there is no ileo-cæcal valve. In the shark, and some other fish, the digestive surface is increased by means of a spiral fold of mucous membrane being wound round the interior of the gut from pylorus to anus. The liver is large. Connected with the stomach are certain diverticula, like the fingers of a glove, numerous in some, as in the Salmon, few in others, as in the Perch, called *appendices pyloricæ* ; these are probably homologous in action to the pancreas.

Circulation.—The heart of fishes is contained within the branchial arches ; there is no true diaphragm to separate thorax from abdomen. The heart consists of two cavities. Its action has been described. The Amphioxus does not possess a true contractile heart, but numerous contractile cavities containing colourless corpuscles situated in the course of the chief blood-vessels.

Respiration.—Water, containing oxygen in a state of solution, is taken into the mouth, and thence passed through the branchial arches, and so comes into contact with the blood contained in the branchial capillaries, which rob it of its oxygen. In addition to the gills, however, an additional respiratory organ exists in most fishes, called the *swimming-bladder*. This is a hollow musculo-membranous sac, situated close to the vertebral column, and often connected by a small tube, the *ductus pneumaticus*, with the œsophagous or pharynx. It is covered by 'retia mirabilia' of blood-vessels, and contains air, which can be renewed, compressed, or expelled. It serves both to assist in purifying the blood, and to lighten the body of the fish. Flat-fish and sharks do not possess a swimming-bladder. It also probably serves, from its occasional connection with the internal ear, as an acoustic organ, and increases the vibration of sound.

Nervous System.—The encephalon is arranged, as has already been said, in an antero-posterior chain of four symmetrical ganglia. The cerebral hemispheres merely form a thin grey coating, which covers the second pair of ganglia, the representatives of the corpora striata. The third pair, or optic lobes, are the largest of all in fishes. The two halves of the medulla are more or less separated by an interval. There is no pons Varolii. The cerebellum consists of a median portion only, evidently the homologue of the vermiform process. The cranial nerves are all present except the ninth. The fifth is large, and sends a considerable branch, the *great lateral nerve*, to supply all the muscles (called myocommas) on the sides of the fish. The pneumogastric supplies the gills.

The sympathetic system resembles that of man.

Even in this, the lowest Vertebrate class, the nervous system is endowed with volition, as well as excito-motor and sensori-motor powers.

SENSES.

Touch.—The folds of membrane in front of the mouth, which serve for lips, the soft parts about the mouth, and occasionally the pectoral fins, are all liberally supplied with nerves, and possess tactile corpuscles ; they are therefore all regarded as organs of touch.

Taste.—The tongue is little developed in fishes, and is never protrudible beyond the mouth. It serves more as an organ of deglutition than of taste. The sense of taste, indeed, is scarcely at all present.

Smell.—The olfactory nerves, which continue the olfactory lobes to the nasal sac or sacs, are rounded cords, and do not divide into filaments. They are distributed to the delicate membrane of the nasal sacs. Sometimes the membrane is plicated. In the Myxinoids and Lepidosirens a tube establishes a communication between the palate and the nasal sacs.

Hearing.—The vestibule with a utriculus, two or three imperfectly developed semicircular canals, and a diverticulum (sacculus), are the only parts of the organ of hearing which exist in fishes. The vestibule always contains an otolith or two, situated in a utricle and saccule suspended in perilymph. No organ of hearing exists in the Amphioxus, which is the lowest of the fish class.

Sight.—The eyes and orbits of fishes are large. The eyeball is more or less flattened ; the sclerotic is very thick ; the lens is spherical and brought close to the cornea ; all which modifications must tend to bring the luminous rays very soon to a focus and adapt the animal only to see accurately objects at a short distance. In addition to the ordinary tissues and humours, the choroid contains between its layers a vasculo-pigmentary structure of a horse-shoe shape, called the 'choroid gland.' Sometimes, *e.g.* in the Sturgeon, this develops a process which passes towards the lens ; this process is called the 'campanula.'

Electric Organs.—Seven species of fish possess electric organs : three are Torpedoes, belonging to the Ray family ; the fourth is the Tetraodon ; the fifth is the Silurus ; the sixth is the Momyrus ; and the seventh, and by far the most powerfully armed of all, is the Gymnotus or Electric Eel.

The electric organs are composed of cells, generally hexagonal, having very large nerves connected with them. One end or surface, as the case may be, of the animal, is positive in its electricity, the other is negative. If the nerves are cut, the electrical power is at once abrogated. The cells contain an albuminous fluid, sp. gr. 1·026.

CHAPTER XXVI.

General Characters of Amphibia—Description of Orders.

Class II. AMPHIBIA (*Batrachia*, Cuvier).

Definition.—Cold-blooded vertebrates that breathe by means of branchiæ during some period of their existence, but possess lungs in addition, sooner or later. Some possess median cutaneous fringes, but never *fin rays.* The skull articulates with the spine by two condyles. The base occipital is always cartilaginous.

The nasal sacs communicate with the pharynx.

Some Amphibia retain their gills through the whole of their life: these are called *Perenni-branchiata,* and comprise the Proteus, Siren, and Axolotl; others lose their gills after a time, and breathe by lungs only; these are called *Caduci-branchiata,* and comprise frogs, toads, and newts. The metamorphoses which the aquatic-breathing tadpole passes through in becoming changed into the aërial-breathing frog are as follows: The tadpole is, to all intents and purposes, a fish, unpossessed of limbs, but provided with four vascular ciliated plates or branchiæ. There is no tongue. The intestine is a close double spiral tube, adapted by its length and complexity to assimilate the vegetable food which forms its pabulum.

As soon as the gills are thoroughly developed, the lungs commence as simple elongated sacs, which project backwards into the abdominal cavity; they develop as the gills dwindle and shrink away. The intestine becomes shorter, straighter, and much wider, fitting the animal for a carnivorous diet. A tongue and well-formed teeth make their appearance. The upper and lower jaws become ossified. The limbs become gradually developed, the fore legs first, and finally exhibit all the bones, in an easily recognisable way, which are present in the human limbs. As soon as these changes are complete the tail drops off, and the animal respires air only; in other words, changes from a tadpole to a frog.

Amphibia possesses a larynx and are endowed with powers of vocalisation.

The changes which the organs of circulation undergo during the metamorphosis are considerable. The heart is at first bilocular and respiratory, resembling indeed the heart of a fish. During the development of the lungs, the pulmonary veins begin to grow from the fourth branchial arch, and, increasing in size, finally contain all the blood formerly sent to the gills; after being exposed to the oxygen in the lungs, the blood is returned by the pulmonary veins to a separate auricle, the left, so that the heart has now become trilocular; the single ventricle contains the mixed blood, pure from the lungs and impure from the rest of the body.

Contractile muscular sacs called lymph hearts, in connection with the lymphatic system, are always present in Amphibia.

Amphibia contain the following orders:—

Order 1. Urodela (Ichthyomorpha, Saurobatrachia); *e.g.* Newt, Proteus.

,, 2. Anoura (Batrachia, Theriomorpha, Chelonobatrachia): *e.g.* Frogs and Toads.

,, 3. Gymnophiona (Ophiomorpha, Apoda, Ophiobatrachia): *e.g.* Cecilians.

,, 4. Labyrinthodontia: *e.g.* Labyrinthodon.

Order 1. **Urodela** (*οὐρά*, a tail; *δῆλος*, visible): the tailed Amphibia. There is no exoskeleton. The tail, which persists, is flat or round. The vertebræ are amphicœlous, or opisthocœlous, and support short ribs. The bones of forearm and leg present us with the usual elements met with in the mammalian class, that is, there is a radius and ulna in the arm, and a tibia and fibula in the leg. Urodela comprise both Perenni-branchiata and Caduci-branchiata.

Perenni-branchiata. Type form *Proteus anguineus.* An Amphibian, a foot in length, found in Illyrian caves. It is a white newt with scarlet branchiæ. Eyes rudimentary; indeed the Proteus is said to be quite blind. The *Siren* and *Axolotl* belong to the same group.

Caduci-branchiata. Type form *Triton* or Water Newt. The larval forms are tadpoles, possessing gills up to the third month. The adult has no gills, but a persistent tail. The males have a crest on their backs. The Salamander belongs to this group.

Order 2. **Anoura** (*ἀνά*, without; *οὐρά*, a tail), or Batrachia. Tailless Amphibia. Comprise Frogs and Toads. Exoskeleton absent. Vertebræ procœlous or opisthocœlous. Ribs when present are rudimentary, or they may be absent altogether. The bones of the forearm and leg are anchylosed into single bones. The astragalus and os calcis are much elongated. Hind legs are natatory organs, and are much larger than the fore legs. Respiration aquatic in larval, aërial in adult forms. The larvæ or Tadpoles are hatched directly from the spawn ; they live an aquatic life, swimming like fishes by means of a vertical tail ; when the change towards froghood commences, the complex coiled intestine of the phytophagous Tadpole becomes changed into the simple and straight canal of the insectivorous Frog, teeth appearing during the metamorphosis upon the mandible, maxillæ, and premaxillæ. After the lungs are formed, which commence as blind sacs, the external branchiæ shrivel, and the tail is left entirely behind. The tongue is attached anteriorly and free behind. In the Surinam toad the eggs are lodged in little pouches upon the back, formed by involutions of the integument : in these sacs the young are hatched. The skull of frogs is peculiar in possessing a bone which passes circumferentially round the greater part of the front of the skull ; this is the girdle bone, as Cuvier called it, the *os en ceinture,* and represents the ethmoid, prefontals, orbits, and sphenoids all ossified together into one bone. After the tail drops off, the terminal portion of the notochord is converted into a bone called the urostyle.

Order 3. **Gymnophiona** (γυμνός, naked ; ὄφις, a snake), often called Cecilia. Exoskeleton soft, with small scales embedded. Vertebræ amphicœlous. No limbs. The mandible is well developed. Teeth long, recurved. Ribs numerous. No sternum. Anus near the end of the body. Tongue not protrudible. Larval form has branchiæ, the adult lungs, but three branchial arches persist throughout life in Cecilia. The Cecilia are worm-like animals, from three to four feet long, inhabiting the East Indies, Ceylon, and South America.

Order 4. **Labyrinthodontia.** All extinct Amphibia, found chiefly in the Triassic strata ; their footprints are not uncommon, but the animals themselves are rarely found. The footprints closely resemble an impression of a gigantic human hand with the thumb outstretched. They were large frog-shaped amphibians, with a strong exoskeleton and amphicœlous vertebræ. They derive their name from the labyrinthine foldings or plaits which are found in the upper portion of their teeth when a section is made through them.

CHAPTER XXVII.

Physiology of Amphibia.

Digestion.—The changes from the vegetable-feeding Tadpole to the carnivorous Frog have been described. The alimentary canal is peculiar in this class, in that it has no ileocæcal valve to mark the distinction between large and small intestine.

Circulation.—In the *Caduci-branchiata* the circulation changes from that of a fish to that of a reptile. The heart at first consists of a single auricle and a single ventricle ; the ventricle forces the blood into the dilated commencement, called *bulbus arteriosus,* of a large artery ; this transmits it by four vascular arches to the gills, which, at first *external,* have given place to four *internal* laminated plates. From the gills it is collected by branchial veins and poured into a large dorsal vessel, which transmits it to every part of the body. As the animal gradually changes from a water-breathing to an air-breathing creature, these vascular arches change too ; from each arch small vessels pass directly down and empty their contents into the descending aorta ; these enlarge until all the blood enters them ; the upper three constitute permanent channels, connecting the bulbus arteriosus and descending aorta ; the fourth or lowest becomes, as the lungs develop, the pulmonary artery ; the blood is returned from the lungs by pulmonary veins, which enter a superadded auricle, from which it is poured into the single ventricle. In some cases there is a partial septum developed in the ventricle, so far as to foreshadow the perfectly four-chambered heart of birds and mammals. In the *Perenni-branchiata,* the three upper vascular arches continue through life to supply blood to the gills ; the fourth becomes the pulmonary artery as in the former instance.

Absorption.—The lymphatics are few in number, large in size, and unprovided with valves. Lymphatic hearts, which possess unstriped muscular walls, and contract rhythmically, but not synchronously with the heart, are present. In the frog there are four of these hearts—two in the neck and two in the pelvis.

Respiration.—The *Perenni-branchiata* always respire both by lungs and gills. These gills are *external* and *plumose*, and always *ciliated* ; they project freely into the water. The *Caduci-branchiata* breathe for a short time only by external gills ; these give place to internal gills, placed in a branchial chamber : they are homologous to the gills of fishes, and are converted into lungs. The lunged *Caduci-branchiata* swallow air ; it is first collected into a sort of musculo-membranous bag connected with the hyoid bone ; the nostrils are then closed, and the air forced by muscular contraction of the sac-walls into the lungs ; the *Caduci-Branchiata* also respire by their skin.

The *Nervous System* is in the lowest Amphibia (Perenni-branchiata) essentially the same as in fish ; in the highest Amphibia (Caduci-branchiata) essentially the same as in Reptilia.

Senses.

Touch is much more perfect than in fish ; the lips, the limbs, and the general soft skin all being seats of the sense of touch.

Taste.—The tongue is a prehensile or tactile organ rather than an organ of taste.

Smell.—There are two posterior nares communicating with the pharynx. This sense is more highly developed than in fishes.

Hearing.—The auditory organ is lodged in bone or cartilage and consists of a vestibule and three semi-circular canals. It has always an external aperture covered with membrane. In the midst of the foramen ovale, a plate of bone is fitted, which is attached by a rod of bone or columella, the homologue of the stapes, with the membrana tympani. Otoliths and perilymph are present and a Eustachian tube in the higher Amphibia.

Sight.—There are eyelids, but still no lachrymal apparatus. The oblique muscles in the frog arise one above the other from the inner angle of the orbit. A *membrana nictitans* is present. The other parts of the eye resemble the same organ in fish.

CHAPTER XXVIII.

General Characters of Reptilia—Description of Orders.

Class III. REPTILIA.

Definition.—Cold-blooded Vertebrata that respire by means of lungs.

The lungs are imperfectly cellular, and are situated in a common thoracico-abdominal cavity. The heart is three-chambered, containing two auricles, and one ventricle, which is sometimes divided by a median septum. The skull articulates with the spine by means of a single condyle. The basi-occipital is ossified. The lower jaw does not articulate directly with the skull, but is separated from it by means of a strong bone, the *os quadratum.*

The tarsus and metatarsus are never ossified to form a single bone, as is always the case with birds. Each half of the mandible is often formed of from four to six pieces, and one side frequently articulates with the other by cartilage or ligament, which arrangement enormously increases the gape. Endoskeleton completely osseous, and ribs well-formed. Exoskeleton formed either of horny scales, or of large plates of bone which may enclose the animal as in a box. Diaphragm absent. Lungs large, but not finely cellular. Oviparous or ovo-viviparous in reproduction. Visceral arches and clefts are persistent.

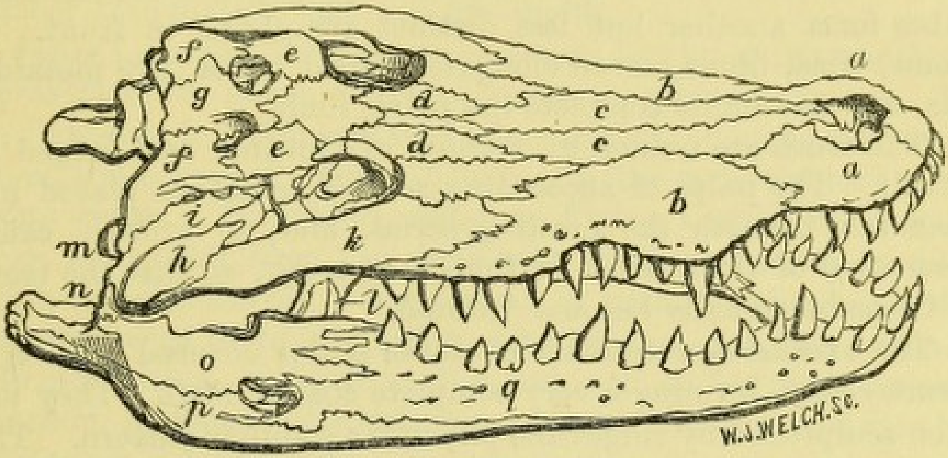
Reptilia contain the following orders, the first four of which are living, and the rest extinct :—

Order 1. Crocodilia.	Order 6. Plesiosaura.
,, 2. Lacertilia.	,, 7. Dicynodontia.
,, 3. Chelonia.	,, 8. Pterosauria.
,, 4. Ophidia.	,, 9. Dinosauria.
,, 5. Ichthyosaura.	

Order 1. **Crocodilia**—comprising Crocodiles, Alligators, and Caimans—have very perfect skeletons. A Crocodile (*e.g.*)

possesses four cranial vertebræ, nine cervical, thirteen dorsal, two or three lumbar, two sacral, and about thirty caudal vertebræ, in most of which a neural and a hæmal arch can be made out, with the usual processes and appendages. They possess no clavicles, a circumstance that may almost always be predicated of animals with prone limbs. False ribs are developed from the front of the abdomen, which have their homologues in the transverse striæ of the human rectus.

Fig. 48.



SKULL OF CROCODILE.

a. Premaxillaries. *b.* Maxillaries. *c.* Nasals. *d.* Prefrontals. *e.* Postfrontals. *f.* Mastoids. *g.* Parietal. *h.* Squamosal. *i.* Tympanic. *k.* Malar. *l.* Pterygoid. *m.* Paroccipital. *n.* Articular. *o.* Angular. piece. *p.* Angular. *q.* Dentary.

The ventricular septum in the Crocodiles is quite complete, thereby rendering the heart perfectly four-chambered and placing this order in advance of the other reptilia.

All living Crocodilia have procœlous vertebræ; in most of the extinct genera they were amphicœlous, and in one genus, *Streptospondylus*, they were opisthocœlous. The cervical vertebræ, beginning with the atlas, are supplied with ribs as well as the dorsal vertebræ.

The bones of the skull are united by suture, and the homologies of the separate bones to those of the fish's skull on the one hand, and to those of the bird's skull on the other, can readily enough be made out. An interorbital septum exists in all Crocodilia. Large horizontal palate processes are developed from the maxillæ and palate bones, which cut off the nares from the mouth; the nares, which are single, open very far back, owing to the length of this hard palate. The mandible articulates with the skull through the intervention of a very large *quadrate* bone, which is anchylosed to the skull. The tympanic cavities are enclosed in complete osseous boxes, but they communicate with each other across the base of the skull by air-passages.

As to the upper limbs, there is no clavicle, but a coracoid and scapula are present which articulate with a humerus, and this in turn with a radius and ulna: the carpus is formed of nine somewhat elongated bones which articulate with five metacarpals, and these again with five digits.

In the lower limbs the ilia are large and joined to the sacral ribs. The ischia unite with each in a symphysis below, and the pubes form another but less distinct symphysis in front. A femur, tibia, fibula, seven elongated tarsal bones, five metatarsals, and five digits complete the pelvic limb.

The teeth are numerous, formed of dentine, and lodged in alveoli. The pulps of succeeding sets of teeth are placed immediately beneath the existing series, and, in growth, cause absorption of the interior of the older tooth, so that the teeth of Crocodiles finally become 'nested.'

The exoskeleton consists of dense scutes covered with epidermic scales, forming a very complete coat of mail. They are often sculptured by ridges and pits into a complex pattern. The scutes are often united by suture.

Crocodiles can be distinguished from Alligators by the fact that the fourth tooth on the lower jaw is larger than the rest, and projects on each side of the snout; this is not the case in the Alligator. Crocodiles again have webbed feet, and infest rivers. Alligators have rounded, not webbed feet, and inhabit the marine mouths of rivers. The amphicœlous and opisthocœlous Crocodilia are all found in the Mesozoic strata.

Order 2. **Lacertilia**—comprising Chameleons, Blindworms, and Lizards—are distinguished from the other classes by possessing clavicles, and their teeth not being lodged in sockets, as is the case in Crocodilia. The heart is three-chambered. Vertebræ procœlous or amphicœlous, never opisthocœlous. Ribs are present, but limbs may be absent, or, if present, are either two or four in number. Sacrum consists of three vertebræ. Ribs are often developed from the cervical vertebræ, which number from seven to nine, as well as from the dorsal vertebræ.

The skull of Lacertilia is intermediate in type between the skull of Crocodilia and that of Chelonia. The bones are often anchylosed, but the front part of the skull can sometimes be moved upon the occipital region, owing to the intervention of a membrane between the two. The quadrate bone as a rule is not united to the skull by bone. When all four limbs are present, as in Chameleons, the pectoral arch presents a scapula, coracoid, clavicle, and interclavicle; and the pectoral limb, a humerus, radius, and ulna, nine carpal bones, five metacarpals, and five digits. In the Chameleons, however, we find that the five distal bones of the carpus being grouped around the os centrale, have become united with the metacarpus, the three proximal only being free. The pelvic arch consists of ilia, movably joined to sacrum, ischia, and pubes, both forming symphyses, a femur, tibia, and fibula, tarsal bones varying in number, five metatarsals, and five digits.

Some Lacertilia have no exoskeleton, but most frequently it is present in the shape of scutes, or horny plates or spines. In the *Iguanidæ* it is elevated into a dorsal crest, or mane, of horny scales, and covers the throat-pouches in the same animals with strong scutes. The *Draco volans*, or Flying Lizard, has a cutaneous expansion from the false ribs which enables it to take flights through the air. The tongue in many of the Lacertilia is a bifid organ of touch, but in Chameleons is a long, round, muscular organ, clubbed at the end, and coated with a viscid secretion, by means of which it catches vast numbers of flies by shooting it out with extraordinary speed.

Order 3. **Chelonia** comprise the turtles and tortoises. The exoskeleton and endoskeleton together form the very singular box in which these animals live; it consists of a dorsal shield, the 'carapace,' and a ventral shield, the 'plastron.' The so-called 'tortoise-shell' is formed by the exoskeleton.

There are eight cervical, ten dorsal, two sacral, and eight caudal vertebræ. The cervical and caudal vertebræ are movable, the rest are all immovable. The cervical vertebræ have no transverse processes or ribs. They are peculiar in the fact that some are procœlous, others biconvex, and others opisthocœlous. The dorsal vertebræ are very remarkable. The neural spines are immensely expanded, joined to each other, and together with the ribs, form the under part of the dorsal shield or carapace; the extremities of the ribs articulate with a number of *marginal* bones, to which the plastron is appended. The plastron is regarded by some naturalists as the sternum, and by others as a dermic growth. It is usually composed of nine pieces, one being median and central, the other eight being arranged in four pairs on either side; the central piece, supposing the plastron to be a true sternum, is the *entosternum*, and the other four from above downwards, the *episternum*, *hyosternum*, *hyposternum*, and *xiphisternum*. By those who regard it as a dermic growth, the similar pieces are called *entoplastron*, *epiplastron*, *hyoplastron*, *hypoplastron*, and *xiphiplastron*.

The skull of Chelonia is formed of bones which with the exception of the mandible and hyoid bone are firmly united together. The pro-otic and opisthotic elements of the periotic capsule remain distinct bones, but the epiotic is joined to the supra-occipital. The orbits are large and separated by a plate of bone. The maxillæ and mandible form large horny beaks, so to speak, devoid of teeth, but with edges sufficiently sharp to clip the tough and glairy seaweed on which the Chelonia feed. The vomer is a single bone, while in the Crocodilia and Lacertilia it is double. The os quadratum is anchylosed to the skull.

The pectoral and pelvic arches are contained within the bony box. The pectoral arch consists of a scapula and coracoid, the fore limb of a humerus, radius and ulna, a typically perfect carpus of ten bones, five metacarpals, and five digits. The pelvic arch presents an ilium, ischium, and pubes, both of the latter uniting to form a symphysis, a femur, tibia, and fibula, a tarsus, to which succeed five metatarsals, and an equal number of digits.

The exoskeleton, which covers the carapace and plastron, is formed of large plates; in the carapace there are five central plates, four on each side, and twenty-five marginal plates. The plastron is covered by six pairs of symmetrical plates. The Chelonia are a large order and contain the Land Tortoises (*Testudinea*), River Tortoises (*Emydea*), Mud Tortoises (*Trionychoidea*), and Turtles (*Eureta*).

Order 4. **Ophidia** include the snakes. They have neither scapular nor hæmal thoracic arches; they possess, however, vast quantities of ribs. No trace of any anterior limb exists in any Ophidian, but in a few genera, typically represented by the Boas, a rudimentary pelvis is present. In the genus Tortrix, allied to the Boas, there are abortive hind limbs in addition to rudimentary pelvic bones. The rami of the mandible, or lower jaw, are united only by ligament, and each half can be separately protruded or retracted; this symphysial joint, together with the large movable quadrate bone, which separates the mandible from the skull, enables the Ophidian to open its mouth in every direction to a prodigious extent. The heart is three-chambered.

No animals possess so many vertebræ as Ophidia. The Python has 291, the Rattlesnake 194, and the Boa-constrictor 305.

Each vertebra is procœlous; besides the ball and socket joint which is found between each centrum, a projecting process (zygosphene) is present on either side, and just behind the central depression, which fits into a corresponding depression (zygantrum) in the preceding vertebra.[1] Thus each vertebra has in front a circular pit and two prominences, and behind a round head and two depressions. The skull of Ophidia is not provided with an interorbital septum. The premaxillæ are single and often movable. The quadrate bone is freely movable. Malar bones are not present. The character of their teeth is alluded to in the sketch of the physiology of Reptilia.

The exoskeleton is formed of glittering scutes; they are generally flat and imbricated, the ventral scutes being much larger than the dorsal. Locomotion along a plane surface is effected by these ventral scutes rising and falling, in response to the costal and dermic muscles, like a series of transversely arranged paper-knives. The entire exoskeleton is shed in one piece at certain seasons of the year; the snake during the process seems to suffer from malaise, retires into some quiet spot, makes a ring of his tail through which he threads his body, and so peels off, as it were, the old harlequin suit, the new glittering sheen being already donned beneath. Poisonous snakes always possess a vertical keel running along the centre of each scute, and have flat heads separated from the body by a distinct neck. In the non-venomous snakes, on the other hand, the scutes are not keeled, and the head is not separated by a neck from the body.

The remaining orders are all extinct 'dragons of the slime.'

Order 5. **Ichthyosauria** (gigantic fish-like reptiles, abounding in the Mesozoic period). Vertebræ amphicœlous; transverse processes rudimentary; no sacrum, or sternum, or sternal ribs; limbs in the form of paddles; bones of carpus, &c., showing evidence of 'vegetative repetition;' scapular arch and clavicles present. Pelvic arch not joined to spines. Teeth numerous and formed of folded plates of enamel. The eyes of these marine colossi were much larger than those of any animal now living; in volume they frequently exceed the human head. They had several peculiarities of structure. The globe was protected by a special development of horny plates, situated in the

[1] In the Rough Tree Snake, the hypapophyses, parts of the transverse processes in thirty-two of the anterior cervical vertebræ, most curiously serve as teeth; their sharp extremities perforate the œsophagus, and being tipped with dentine, they serve to break the shells of the little birds' eggs on which this animal preys.

sclerotic or outer tunic of the eye, thus enabling the organ to bear the pressure of a vast superincumbent weight of water; the entire structure eliciting from Dr. Buckland the opinion that it was an optical instrument of varied and prodigious power, enabling the Ichthyosaurus to descry its prey at great or little distances, in the obscurity of night and in the depths of the sea. Type form, *Ichthyosaurus.*

Order 6. **Plesiosauria.** Mesozoic marine reptiles. Vertebræ flat or amphicœlous. Transverse processes long, and ribs present. No sternum or sternal ribs. Cervical vertebræ numerous. Sacrum of two vertebræ. Snout long. Sclerotic formed a bony ring. Limbs in shape of paddles, but ossicles not so numerous as in Ichthyosaurus. Type form, *Plesiosaurus.*

Order 7. **Dycynodontia.** Vertebræ amphicœlous. Sacrum of six or more vertebræ. Cranial bones anchylosed. Snout enclosed in a horny beak like the beak of a turtle. Two large tusks often present in upper jaw. Pelvic arches very massive. Type form *Dicynodon.*

Order 8. **Pterosauria.** Vertebræ procœlus. Sternal ribs present. Sternum broad and carinated. Skull prolonged: avian in type with teeth implanted in alveoli, or else edentulous. Sclerotic a bony ring. Pectoral arch existed but no clavicle. The digits enormously prolonged like the digits of a bat, and batlike, supported an integumental outgrowth enabling the animals to take short flights. Long bones perforated by holes for air. Hind limbs small. Type form, *Pterodactylus.*

Order 9. **Dinosauria.** Vertebræ flat, amphicœlous or opisthocœlous. Sacrum of four or more vertebræ. Pelvic arch avian in type. Pectoral arch present, but pectoral limbs very small. Type forms, *Iguanodon* and *Megalosaurus.*

CHAPTER XXIX.

Physiology of Reptilia.

Prehension of Food, Deglutition, and Digestion.—The four orders of Reptilia differ from each other in their prehensile and digestive organs.

Crocodilia.—The Crocodilia employ their jaws as prehensile organs. Both upper and lower jaws are studded with numerous conical teeth, averaging about thirty, composed of dentine, with sometimes a thin coating of enamel. They are lodged in sockets, and are perpetually renewed from a vascular papilla at the base: this constantly producing new teeth, it comes to pass that they grow one within the other, causing absorption of the interior of the older teeth, and so at last become nested like a series of pill boxes. The tongue is large and fleshy, but not protrudible beyond the jaws. The passage into the larnyx and œsophagus is closed at will by a strong musculo-membranous valve, one fold dropping as a continuation from the soft palate, the other rising from the hyoid bone. The nostrils are at the very tip of the snout, so that the crocodile can hold his mouth under water, frequently containing a living struggling prey, and at the same time breathe with perfect ease (as the nostrils lead *behind* the flood-gate) so long as merely the tip of his snout projects above the water.

Crocodilia are carnivorous; and in consequence the alimentary canal is comparatively short and simple. It is interesting from the resemblance it bears to that of birds. A short œsophagus leads into an almost circular and gizzard-like stomach, so strong are the two lateral muscles which compose its walls; the pyloric aperture, guarded by a valve, is placed near the cardiac extremity; the succeeding intestine is short, the junction of small and great gut being marked by the presence of an ileo-colic valve, but no cæcum; it ends in a cloaca common to it and the urinary and generative organs.

Lacertilia.—The chameleons employ their long muscular clubbed tongue as the chief prehensile organ. The lizards generally use their jaws. The teeth are small, and composed of dentine, cement, and enamel; the alimentary canal approximates to that of the Crocodilia.

Ophidia—Constricting snakes employ the folds of their body as assistant prehensile organs to the simple, numerous recurved teeth which stud, not only the dentary and premaxillary bones, but also the pterygoid and superior maxillary bones. The poisonous snakes possess, instead of teeth on the upper jaw, two poison fangs, which are attached to the superior maxilla; these are connected by their base with the interior of the poison bag, which occupies the temporal fossa, and whose secretion is poured out, when the mouth is widely opened, by the action of the external pterygoid and temporal muscles which cover it. The poison flows down a groove in the tooth, formed by the projection and overlapping of two of its edges; it opens a short distance from the point, so that the fang must be well implanted before the poison can enter the victim. They are so much recurved as to lie flat against the roof of the jaw when the mouth is closed; they are lodged in a sort of scabbard of mucous membrane, and are constantly renewed, when lost, by a vascular dental pulp situated posteriorly. All the viscera, including the alimentary canal, present the same elongated character as does the body of the snake: the intestine is comparatively short and wide.

Chelonia capture their prey with their jaws, which are edentulous and horny, like the beak of a bird. Chelonia are phytophagous, and the alimentary canal is long and complex in consequence; for convenience of stowage it is arranged generally in a *transverse* direction. Both an ileo-colic valve and cæcum are present. The œsophagus has large recurved epithelial papillæ, which entangle the slippery fuci which form their food, and breaking it off, assist the jaws as manducatory organs. Both stomach and intestines are notably muscular.

The salivary glands are large and abundant in Reptilia, especially so in Ophidia. A liver and gall-bladder are present in all.

The lymphatics are well developed, and lymphatic hearts are present in the neck of certain Ophidia.

Circulation.—The heart is three-chambered, consisting of two auricles and one ventricle which distributes a mixed blood to the lungs and to the body. In the Crocodiles, however, we find the inter-ventricular septum complete, the heart thus having four distinct chambers. In the lower reptiles the ventricle is quite simple, but gives rise both to a pulmonary artery and aorta; in the higher reptiles a ventricular septum exists, which pretty efficiently keeps the venous and arterial blood separate. In the higher reptiles there are two aortic arches, a right and a left—the right being the larger—which arch over the roots of their respective lungs and meet in front of the vertebral column in a common aorta, to supply the hind parts of the body. In the lower reptiles there are three aortic arches on either side, the two upper of which give off branches to the head and neck ; the lower gives off the pulmonary arteries ; finally all unite to form the abdominal aorta.

Respiration.—No reptiles, except the Crocodile, exhibit the slightest trace of a diaphragm ; all swallow the air, much as the Frog does. In Crocodilia and Lacertilia the movable ribs and sternum assist the respiratory movements ; in Ophidia there are nothing but ribs, and expiration is partly the result of the resiliency of the lungs ; in Chelonia the movements exactly resemble those of the Frog ; for though ribs and sternum both exist, they are perfectly fixed. The lungs are large, frequently unsymmetrical (in Ophidia only one is fully developed), and saccular, or imperfectly cellular. The trachea does not branch into bronchial tubes throughout the interior of the lungs, but ends abruptly in their substance, so that the air is renewed but slowly and imperfectly.

Renal Organs.—The kidneys are large, and pour their contents into two ureters, which open into the common cloaca. There is no urinary bladder. The kidneys, as in all Vertebrata below Mammalia, consist of cortical substance only.

Nervous System.—The olfactory lobes are uncovered in front ; the optic lobes, which are *bigeminal*, as in fish, are uncovered behind the cerebral hemispheres. The medulla oblongata supports a cerebellum, which still consists merely of a median portion. The cerebral hemispheres are hollow, exhibiting the first trace of lateral ventricles. The optic lobes likewise contain a cavity in their interior. The cerebral hemispheres are now, however, the largest of all the cerebral ganglia. A ninth nerve is present.

Senses.

Touch is but ill developed ; but the varieties of the tegumental growths are great. The osseous plates of the Crocodile, the scutes (the principal organs of locomotion) of the Ophidia, the granular coat of the Chameleon, the horny coverings of the plastron and carapace of Chelonia, are all developments of the cutis.

Taste.—The bifid tongue of Ophidia, the long, worm-like tongue of the Chameleon, and the freely movable tongue of

Chelonia, are all rather tactile organs than instruments applied to discriminate sapid substances ; the sense of taste, indeed, is scarcely at all developed.

Smell.—The mucous membrane of the nose is plicated, but the sense of smell is imperfect. In Crocodilia and Lacertilia the nostrils open into the pharynx ; in Ophidia and Chelonia into the mouth.

Hearing.—All reptiles, except Ophidia, possess a tympanic cavity with ossicles, in which we recognise an incus, malleus, and stapes, a membrana tympani, and Eustachian tube. Ophidia merely possess a single ossicle, the columella, which is embedded in the flesh. The internal ear presents to us now, in addition to a vestibule and three semicircular canals, a rudimentary cochlea, in the form of a short straight canal, which has a slight twist in the highest forms (Crocodilia), imperfectly divided by a median partition into a scala vestibuli and a scala tympani.

Sight.—The tunics and humours resemble those in man. There are no eyelids in Ophidia, the skin being continued over the cornea : but all other reptiles possess them. A lachrymal apparatus is always present. Like the Amphibia the Crocodiles have a third eyelid or membrana nictitans.

CHAPTER XXX.

AVES—GENERAL DESCRIPTION—SKELETON—MUSCULAR SYSTEM OF AVES—STRUCTURE AND DEVELOPMENT OF FEATHERS.

Class IV. AVES.

Definition.—Warm-blooded Vertebrata, clothed with feathers.

The skull articulates with the spine by a single condyle. The basi-occipital bone is ossified. The vertebral column is divided into five very distinct portions—cranial, cervical, dorsal, lumbar, and sacral. The cranial vertebræ are early anchylosed, and it is only in the skull of the young bird that the separate bones can be made out. The lower jaw is joined to the skull by the intervention of the os quadratum, as in Reptilia. The jaws are never provided with teeth. The cervical vertebræ vary in number from nine in the Sparrow to twenty-five in the Swan; they are freely movable on each other, and permit the head to be turned in every direction for prehensile purposes. The dorsal vertebræ are firmly anchylosed together to give stability to the great muscles, the agents in flight, which take their origin here. The hæmal arch is entirely bony, and the sternum presents a strong median ridge, or keel, which vastly increases the surface of origin of the pectoral muscles. In a few birds, the cursorial or running order, the keel is absent from the sternum. The lumbar and sacral vertebræ are few but strong; the caudal vertebræ are rudimentary, the posterior segments being ossified together to form the 'pygostyle' or 'ploughshare' bone, which gives firm attachment to the tail feathers, and also supports the 'uropygium,' or oil gland. In an extinct bird of the Mesozoic period, the Archeopteryx, the vertebral column is terminated by a veritable tail of caudal vertebræ.

The trachea is furnished with two larynges: one in the usual situation, at the upper part, and one, called the syrinx, which is the principal organ of voice, situated at the bifurcation of the trachea into the two bronchi.

Aves differ from Reptilia in their blood being hot; in there being only one aortic arch, the right; in the fore limbs never possessing more than two digits terminated by claws; and in the fact that the *corpora bigemina* are placed at the sides and not on the under surface of the brain.

Aves differ from Mammalia in the atlas only possessing a single facet; in the presence of an os quadratum intervening between the mandible and skull; in the cervical vertebræ being more than seven in number, and in possessing no lips, teeth, epiglottis, diaphragm, fornix, corpus callosum, or scrotum.

Skeleton of Aves.—The bones of birds are extraordinarily compact and ivory-like. In the hawk, for instance, 100 parts of bone contain 73·28 earthy material, and 26·72 animal matter.

Vertebral Column. Cervical Vertebræ.—Very flexible, as it is only by the free movements of the neck that the bird can pick up food from the ground. To subserve this end the neural spines are very short, or even entirely abortive. The centra fit into each other by saddle-shaped surfaces, being concave from before backwards, and convex from side to side. The atlas is a mere ring of bone, its body being always appended as an odontoid process to the body of the axis.

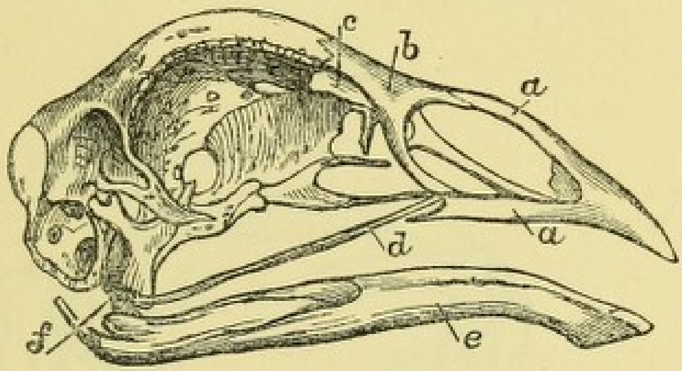
Dorsal vertebræ.—Much consolidated; they vary in number from four to eleven. The hæmal arch is entirely osseous. Pleurapophyses (ribs) articulate both with diapophyses and parapophyses of vertebræ. The sternum in all birds of flight presents a median keel (hence these birds are called *carinatæ*), to afford increased space for the attachment of the great pectoral muscles. It also gives great strength to the chest without materially adding to its weight, just as a vertical beam of metal placed on a horizontal plane in the so-called T-iron yields a result of extraordinary strength.

Sacral vertebræ.—From seven to twenty in number. All firmly anchylosed to form a strong bony girdle for supporting the lower limbs. At the middle of the sacrum the neural spines are undeveloped, the transverse processes alone being present, which gives it a wide, flat aspect in this region. As the lumbar vertebræ are welded to the sacral, it is difficult to distinguish between the two.

Caudal Vertebræ.—From six to nine. As a rule they are short, stunted bones, tilted upwards from the sacrum for the attachment of the rudder-tail feathers, called 'rectrices.' The whole caudal vertebræ are anchylosed to form the *os en soc de charrue*, or ploughshare bone. The coccygeal gland, or uropygium, rests like a small pommade pot on these caudal vertebræ. In the Archeopteryx the caudal vertebræ were numerous, and constituted a true bony tail.

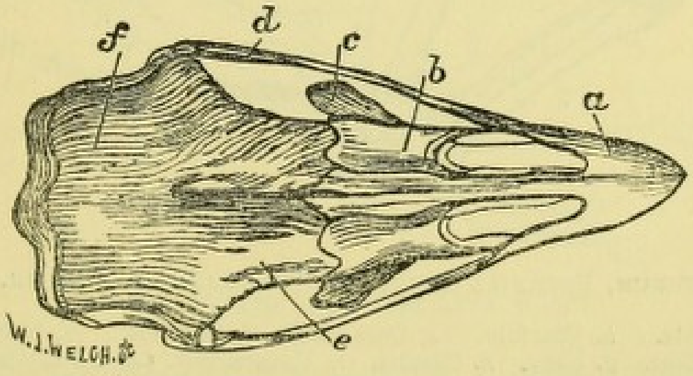
Cranium.—Very hard, but very light. The orbital cavities are unusually large, and communicate with each other, and also with the temporal fossæ. The nares also communicate with each other. The separate bones are so soon united together that the separate elements can only be made out

Fig. 49



LATERAL VIEW OF THE SKULL OF A FOWL.

a. Premaxillary. *b.* Nasal. *c.* Lachrymal. *d.* Maxillary. *e.* Mandible. *f.* Quadrate bone.

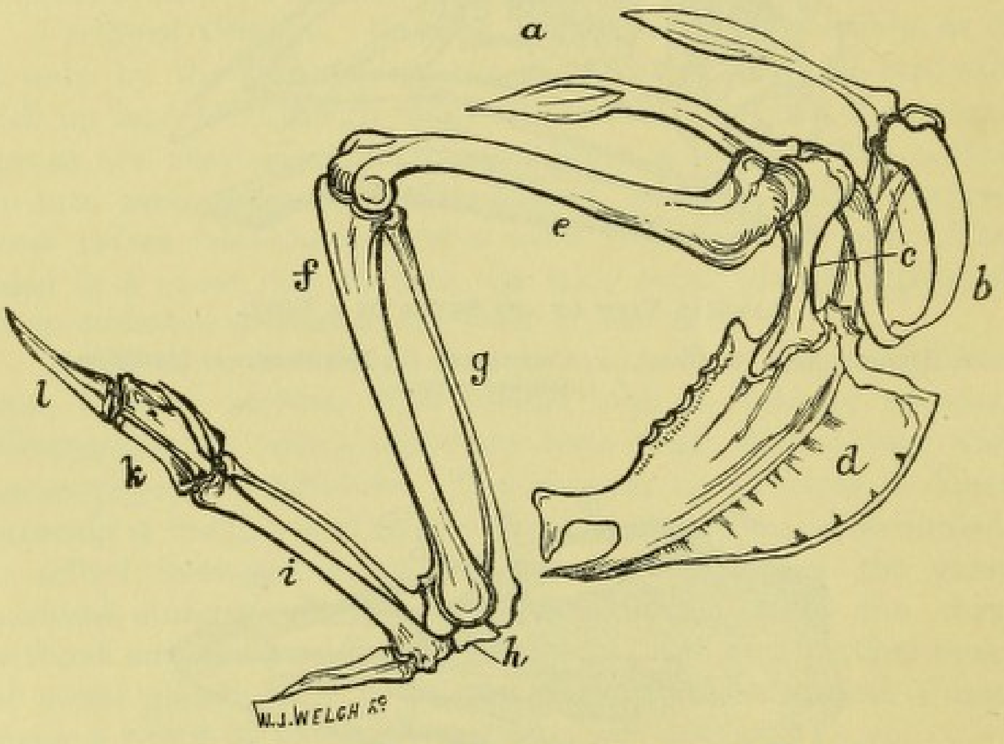


UPPER VIEW OF THE SKULL OF A FOWL.

a. Premaxillary. *b.* Nasal. *c.* Lachrymal. *d.* Maxillary. *e.* Frontal. *f.* Parietal.

during the development of the bird, at which period they are found to approximate very closely to the reptilian type. The basi-occipital forms the greater part of the single condyle which articulates with the atlas, but is slightly assisted by the exoccipitals; the paroccipitals form outstanding buttresses; the superoccipital is flattened. In the succeeding segment the usual elements are discernible at an early date, and the parietals (neural spines) are double. In the third segment the orbito-sphenoids (neurapophyses) are small, and have coalesced with the pre-sphenoid (centrum); the post-frontal (parapophysis) is also small. The vomer (centrum of nasal segment) also joins pre-frontal and palatines (pleurapophysis), and is deeply grooved above. The large size of the eye-capsule in birds is, however, perhaps the feature which strikes an observer most. As to the hæmal arches of the cranial vertebræ, the hyoid arch (hæmal arch of parietal segment) is formed of a small basi- and cerato-hyal, and of a large glosso- and uro-hyal. The os quadratum

Fig. 50.



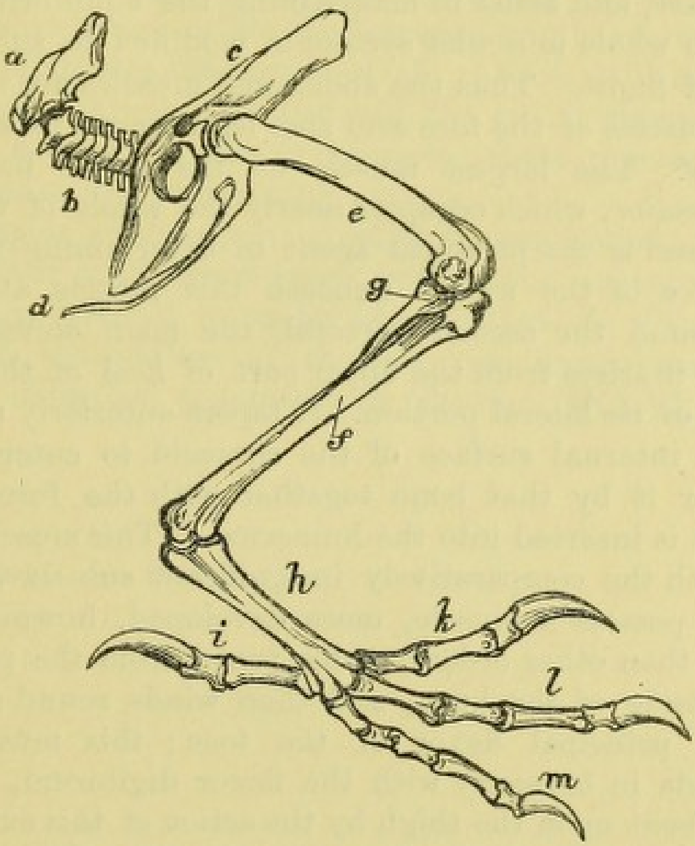
STERNUM, PECTORAL ARCH, AND FORE-LIMB OF A HAWK.

a. Scapula. *b*. Clavicle. *c*. Coracoid. *d*. Sternum. *e*. Humerus. *f*. Radius. *g*. Ulna. *h*. Carpus. *i*. Metacarpus. *k*. *l*. Phalanges.

is movably articulated with the skull, and intercepts the lower jaw from the cranium. The pre-maxillæ, maxillæ, and palatine bones are united to form a single bone; they are joined to the os quadratum by the pterygoid and jugal bones.

Scapular Arch and Pectoral Limb.—The scapula is a rib-like bone placed parallel to the spine and anchylosed to the coracoid, which is the strongest bone of the shoulder-girdle; together they form the glenoid cavity. The clavicles are comparatively slender bones; they are nearly always present, and arch forwards to meet in the mesial line, forming the *os furculum*, or 'merry-thought.' The clavicle is the most variable of all the bones of the shoulder, being long and strong in the Raptorial birds, and even entirely absent in the ground-parrots of Australia. The humerus is long, strong, and generally pneumatic. Of the two bones of the forearm the radius is always the slenderer bone, the ulna articulates with the scaphoid and semilunar bones, and two sets of metacarpal bones and phalanges make up the claw.

Fig. 51.



PELVIS AND HIND-LIMB OF A HAWK.

a. Ploughshare bone, or *Os en soc de charrue*. *b*. Sacral vertebræ. *c*. Os innominatum. *d*. Ossified tendon. *e*. Femur. *f*. Tibia. *g*. Fibula. *h*. Tarso-metatarsal bone. *i*, *k*, *l*, *m*. Phalanges terminating in hooked claws.

The Pelvic Arch and Hind Limbs.—The pelvic arch is strong and firmly knitted to the anchylosed sacral vertebræ; the three elements of ilium, ischium, and pubes are only distinguishable in the young bird; the pubes do not meet in front, except in the ostrich, hence there is no symphysis or pubic arch. The femur is a strong but shortish bone; it is pneumatic only in running birds, as *e.g.* the ostrich. The tibia is the principal bone of the hinder extremities; it is long and strong. The tarsus and metatarsus are soldered together to form one bone—the *tarso-metatarsal*. Anteriorly this bone supports the toes; posteriorly, the hallux. The toes are usually four in number; in some varieties of the common fowl, however, a fifth toe is found, and the number of phalanges in each toe is constant; thus there are, counting from the hallux, two for the first, three for the second, four for the third, and five for the fourth.

Muscular System.—The muscles of birds are pre-eminently red and irritable; they are chiefly massed on the inner side of the thighs, beneath the sternum and beneath the pelvis; they act as ballast, and assist in maintaining the equilibrium of the bird. The whole muscular system is modified to subserve the function of flight. Thus the abdominal muscles are very small, and the muscles of the fore arm and leg reduced to a mere set of tendons. The largest muscle of the entire body is the *pectoralis major*, which occupies nearly the whole of the keeled sternum, and is the principal agent in determining the downward stroke of the wing. Beneath this muscle, at its upper part, is found the second pectoral, the main elevator of the humerus; it arises from the upper part of keel of the sternum and much of its lateral portion. It tapers anteriorly as it passes along the internal surface of the coracoid to enter the canal formed for it by that bone together with the furculum and scapula: it is inserted into the humerus. This muscle is homologous with the comparatively insignificant sub-clavius of man. All birds possess a muscle, more developed, however, in the Scansores than other orders, which passes from the pubes down to the outside of the knee, and then winds round and blends with the principal flexor of the toes; this muscle consequently acts in harmony with the flexor digitorum, and when the leg is bent upon the thigh by the action of this extensor, the flexor digitorum bends the toes, and so enables the bird to perch or roost with perfect safety.

There is no exoskeleton, but the integument is clothed with feathers.

Development and Structure of Feathers.—Feathers are dermic growths, developed from papillæ within little sacs, the surface of the papilla being marked by a mould of the future feather in miniature. This mould is pushed up from below by a repetition of the process by which itself was formed, and in rising it expands and unfolds, increasing in size, but not materially altering in shape. A feather consists of a *barrel*, or *quill*, a *shaft*, and a *vane*. The vane in its turn consists of lateral barbs, and little vertical hooked barbules. The barbules hook into each other by a system of pot-hooks, which gives the light feather considerable power of resistance to the air. The feathers are trimmed or *preened* by the bird running its beak between the barbs, and in so doing rearranging the latching, so to speak, of the barbules.

Feathers receive different names on different parts of the bird's body. The feathers clothing the body are called *clothing* feathers; the great quill tail feathers, so useful in steering the bird in its flight, are the *rectrices*; those lying over the humerus and scapula are the *scapulars*; the proximal end of the ulna is covered with the *tertiaries*; the distal end of the same bone with the *secondaries*; while the bones of the hand support the *primaries*, which are the largest of all. Each quill often bears a little light feather, just beneath the commencement of the vane, the *accessory plume*, or *plumule*; these plumes form the greater, lesser, and under wing coverts.

The organs of digestion, circulation, respiration, and excretion, together with the nervous system and organs of reproduction, are referred to under the head of the *Physiology of Aves*. The composition of the egg, and development of the chick, are described separately in Chapter XXXVI.

CHAPTER XXXI.

Classification of Aves—Description of Different Orders.

Birds are divided into two legions—Autophagi and Heterophagi; the former immediately on their escape from the egg can run about and look after themselves; the latter are dependent upon their mother for nourishment for some time after birth.

		Autophagi.	
Order	1. Natatores	Swimmers	Duck.
,,	2. Grallatores	Waders	Heron.
,,	3. Cursores	Runners	Ostrich.
,,	4. Rasores	Scratchers	Common Fowl.
		Heterophagi.	
,,	5. Columbæ	Pigeons	Rock Pigeon.
,,	6. Scansores	Climbers	Parrot.
,,	7. Passeres	Perchers	Sparrows.
,,	8. Raptores	Raveners	Hawk.

By other naturalists Aves are divided into three orders—*Saururæ*, *Ratitæ*, and *Carinatæ*. The *Saururæ* contain the Archeopteryx alone; the *Ratitæ* contain the Rhea, Apteryx, Ostrich, and Cassowary; the *Carinatæ* comprise all other birds whatsoever. The Carinatæ are divided into four sub-orders:—

1. Dromægnathæ.
2. Schizognathæ.
3. Desmognathæ.
4. Ægithognathæ.

This is perhaps a more natural classification than the one first given, but as the former, although entirely artificial, is well known and convenient, it will be adopted here. The following orders, however, are probably of little more than tribal value.

Order 1. **Natatores.** Body boat-shaped; legs with feet webbed to a greater or less extent, placed behind centre of gravity; they walk with a waddling movement on dry land, but their movements in water are very graceful. The uropygium, or oil-gland, is large, and being applied to the feathers by the beak, prevents the bird from getting wet.

The Penguins, Grebes, Puffins, Guillemots, Divers, and Ducks form one division of swimming birds called *Brevipinnatæ*, the feathers and wings being short; in the Penguins they are quite rudimentary, not permitting flight. The legs are placed very far back: the wings assist the webbed feet as paddles, the bird in rapid progression striking the water with them as with oars.

The Cormorants, Pelicans, Gulls, Petrels, and Terns form another group—the *Longipinnatæ*, the wings being large, and endowing the possessor with powers of flight. The beak is hooked and pointed, the tip being often very dense and hard. One of the largest and most beautiful birds of flight, the albatross, belongs to this group.

The Ducks, Geese, Swans, and Flamingoes form a third division, the *Lamellirostres*, in all of which the beak is a soft, horizontally compressed bill, covered with a soft sentient cuticle, supplied with twigs from the fifth nerve, and having fringed sides, which strain the muddy food. Wings of medium size.

Order 2. **Grallatores.** Legs long and stilt-like; tarso-metatarsal bone much elongated; toes generally quite free, rarely semi-palmate; wings large and powerful.

The Rails, Coots, Water-hens, and Jacanas form a group in this order termed *Macrodactylæ*, because the claws are very long: they are four in number, and lobed; wings are not large; beak is somewhat cuneiform, and tail is very short.

The Cranes, Herons, Stalks, Ibis, and Spoonbills form the *Cultirostres*, with elongated, narrow forceps—like bills for fishing with; legs not covered with feathers, and very long.

The Snipes, Woodcocks, Sandpipers, Curlews, Turnstones, Ruffs, Redshanks, and Godwits constitute the *Longirostres*. All possess long and very sensitive beaks grooved by nostrils. Legs of moderate length. Insectivorous in habits.

The Plovers, Lapwings, Bustards, Longshanks, and Oyster Catchers are comprised in the *Pressirostres*. All possess a moderate bill with a compressed tip. Feet semi-palmate. Wings long and strong. Bustards run very swiftly; all the others are capable of rapid and sustained flight.

Order 3. **Cursores.** Wings rudimentary; and useless for flight. The legs are pneumatic, and are very strong and long. In many of the Cursores the sternum is not keeled (*Ratitæ*), in accordance with the small size and power of the pectoral muscles. The Ostrich alone among birds possesses a true subpubic arch, the two pubes meeting anteriorly in a symphysis.

The barbules do not hook into each other, the ostrich plumes being formed of free and independent barbs and barbules.

The Ostriches, Rheas, Cassowaries, and Emeus constitute a group called *Struthionidæ*, characterised by the entire absence of the hallux. This group contains the largest of all birds. The male Ostrich and Emeu take upon themselves all the duties of incubation, relieving their mates of every trouble in the matter. The Emeus and Rheas have three toes on each foot; the Ostrich has but two. The Cassowary is known by a curious cephalic horny crest or wattle: the head and neck are not clothed with feathers. The Apteryx of New Zealand forms a distinct group of Cursores, and is singular in possessing only bare rudiments of wings which end in a claw. Beak long, slender, and compressed. Tail not visible. The habits of the Apteryx are entirely nocturnal. The fossil remains of the Dinornis, a gigantic wingless bird, occurring in the superficial deposits of New Zealand, and related in structure to the Apteryx, have been placed in this order.

Order 4. **Rasores** or **Gallinaceæ**. Beak is a short, strong forceps; the upper bill or maxilla being vaulted. Legs feathered nearly to the tarso-metatarsus. There are three anterior toes and one posterior. The anterior are blunt and adapted to scratching. Gizzard immensely strong.

The common Fowl, Turkeys, Partridges, Grouse, Pheasants, Ptarmigan, and Pea Fowl form a group called *Climatores*. The wings are short and not very powerful. There is a rudimentary toe placed at the back of the tarsus, and called the *calcar* or spur; it forms a strong weapon of attack.

Order 5. **Columbæ** differ from Rasores in possessing powerful wings, and in leaving the egg in a very helpless and dependent condition. In other words, they are heterophagous, and not like the rasorial birds, autophagous. Pigeons, Doves, and the extinct Dodo are found in this order. The Dodo was a bird of the Kainozoic period, and differed widely from the gentle Doves and Pigeons; it was a large, powerful, and carnivorous bird of prey inhabiting the Island of Mauritius.

Pigeons afford one of the best instances of the mutability of species, or rather of varieties; all the vast number of Pigeons, Carriers, Tumblers, Fantails, and so forth, being all descended from one common stock—the blue-rock Pigeon, or *Columba livia*.

Order 6. **Scansores**. Characterised by having four toes, two directed forwards and two backwards, which enable the birds to climb. The posterior toes are the hallux and the outermost of the three toes, which as a rule are directed forwards: the anterior toes are therefore the first and second. One of the most curious habits of birds is met with in certain birds of this order, *e.g.* the Cuckoos, who do not build nests of their own, but lay their eggs in the nests of other and not closely allied birds. They do not deposit more than one egg in the strange nest ; but when the young Cuckoo is hatched he is so much stronger and larger than his foster brethren, that he sets to work and ousts them from the nests, leaving the rightful owners to perish miserably of cold and hunger. Scansores are both insectivorous and frugivorous in their habits. Besides the Cuckoo, Parrots, Toucans, Trogons, Woodpeckers, and Wrynecks are found in this order.

Order 7. **Passeres.** Most numerous of all the Avian orders. They are recognised by having the two outer toes joined by membrane. Of the two others, one is always directed backwards. Females as a rule are smaller than the males, and clad in much more sombre colours. All quite dependent upon the mother's care when first extruded from the egg, and are often reared in nests of the most beautiful construction. The voice is often exquisitely musical, the plumage very lustrous, and the powers of flight of extreme perfection.

The Finches, with the Sparrows, Larks, Crossbills, Crows, and Hornbills, form one group in this large order, called *Conirostres*, recognised by having a short, strong, roundish, or conical beak, which tapers quickly from a broad base to a short tip. Their habits are various ; some are insectivorous, *e.g.*, some Finches ; others, carnivorous, *e.g.*, Crows ; others, phytophagous, *e.g.*, Hornbills ; and others, omnivorous. The Hornbills and Toucans possess an additional growth in the shape of a hollow excrescence upon the upper bill. Birds of Paradise, a variety of Crow, and many migratory birds, *e.g.*, the Starling, are met with in this division.

The Shrikes, Fly-catchers, Nightingales, Orioles, Robins, Thrushes, Tits, and Warblers form another group, called *Dentirostres*, from possessing an abrupt notch, which gives the appearance of a tooth to the contiguous part of the beak, on the margin of the upper bill, near its tip.

The Humming-birds, Hoopoes, Wrens, Creepers, and Honey Eaters constitute the *Tenuirostres*, in all of which the beak is elongated into a slender forceps for extracting honey or insects from the deep bells of flowers. The plumage often possesses a metallic lustre, and is of the most gorgeous description. The tongue of Humming-birds assists the beak in sucking up the juices of flowers ; it is hollow and bifid.

The Swallows, Martins, Goatsuckers, Kingfishers, and Swifts constitute the *Fissirostres* ; they have a wide but short beak.

During flight the mouth is kept wide open, and any insects which it encounters are retained by a viscid secretion poured out from the mucous membrane. They are thus of great value in keeping down the quantity of flies and gnats, it being computed that a young swallow consumes upwards of 1,000 a day of these insects. Some of these, *e.g.*, Goatsuckers, are nocturnal, hunting their prey at night alone. In Kingfishers the external toe is united to the middle one, and is nearly as long.

Order 8. **Raptores.** The ravening birds are recognised by their beak, which is a formidable weapon with sharp edges and an acute hooked tip. The upper bill overlaps the lower. The toes are four in number, three anterior and one posterior ; all being terminated by sharp hooked talons. Wings very large and very powerful. Legs short, stout, and strong. Young completely heterophagous.

Owls form a division of Raptores, called *Nocturnal Raptores ;* as their name implies, they hunt by night. Their plumage is very soft and downy, especially on the under surface of the wings, rendering their flight almost noiseless, and so enabling them to pursue their prey with silence and success. The cranial bones are pneumatic. There is a circlet of feathers simulating a pinna around the ear, and another, like a fringe of hair, around the face. Tarso-metatarsus thickly feathered. There is no ingluvies or crop. They live on insects, field mice, birds, and frogs. Falcons, Hawks, Eagles, and Vultures form another group, called *Diurnal Raptores.* Eyes smaller than in last group, but very bright, and capable of bearing a bright light. Powers of flight are carried to the highest pitch of perfection in this group, enabling the large and heavy eagle to soar into the highest and rarest regions of the air, and to support himself there as though floating by 'the act of his own lordly will,' and not by the sweepy waftage of his mighty pinions. Many of the Raptores are able by sloping their body and wings to a certain angle to *stand* perfectly still in the air—an exact balance being maintained between the depressing action of gravitation and the elevating influence of the wind. Tarso-metatarsus often covered with scales, rarely with feathers. Ingluvies present. Intestine short and simple. The so-termed 'noble' birds of prey, which kill their prey, have the upper bill furnished with a lateral tooth : this is absent in the 'ignoble' birds of prey, which live on carrion.

CHAPTER XXXII.

Physiology of Aves.

Prehension of Food, Deglutition, and Digestion.—The beak is the bird's only prehensile organ, except in the raptorial and scansorial families (where the foot is also used), and is variously modified in shape according to the habits and food of the bird. 'Thus it is short and strong in the grain-feeders; long and slender in the insectivorous Warblers and Fly-catchers; notched in other insectivorous birds, as in Shrikes; short and gaping in the Swallows and Night-jars, which catch their prey upon the wing: strong and hooked in the rapacious eagles and vultures, which tear up their food; long, conical, and of great strength in the digging Rooks and in the Woodpeckers, which pierce the bark of trees; short, curved, and of great depth in the Parrot tribe, which can crush hard nuts; exceedingly delicate and tapering in the Humming-birds, to enable them to penetrate the tubular corollas of flowers; ponderous and ungainly in the Hornbills, Toucans, and Adjutants; long, strong, and pointed, for the catching of fish, in the Storks and Herons; elongated and suctorial in the Snipes and Sandpipers, which seek their food in bogs or sand; flattened, grooved, and sensitive in Ducks, Geese, Swans, and Spoonbills; or it presents still other forms for holding fish, as in the Pelicans, Pilgrims, Albatross, Penguins, and Auks.'—*Marshall.*

The salivary glands are comparatively small in all birds except the Woodpeckers, in which they attain an enormous size.

The pharnyx is simple. The œsophagus differs very widely in the different orders of birds. Before reaching the stomach the food is generally received into a temporary stomach, called the crop; there is no crop in some aquatic birds, and it is variously fashioned in others where it does exist. Thus in the Pelican the integuments beneath the lower mandible form a large pouch, which serves as a crop; in Swifts and other insectivorous birds the back of the pharynx is dilated into a receiving house for the insect food; but it is in the grain-feeders that the crop attains its largest size; in the common fowl it forms a lateral pouch on one side of the œsophagus, and in the Pigeon it is composed of a bilateral sac similarly situated. The œsophagus is continued downwards from the crop to an expanded portion, called the '*proventriculus*,' or '*ventriculus succenturiatis*': this is the true digestive stomach, and secretes the gastric juice. It is very variously shaped. The 'proventriculus' almost immediately leads into the muscular stomach or gizzard, which is also called the '*ventriculus bulbosus*.' In flesh-feeders the gizzard is comparatively thin, but in grain feeders it is an enormously powerful muscular sac. Stones or gravel are generally present to assist in trituration of the hard, dry food, forming as it were, an organ of mastication. The muscles composing the walls of the gizzard all radiate from two very strong anterior and posterior tendons. A pyloric valve, which is sometimes formed of several folds or ridges, conducts the food into a small intestine. This is short in carnivorous birds, long in the grain-feeders. There is no ileo-cæcal valve, but two cæca are very often present, and in some birds, as in the Grouse, they attain a great size. The large intestine terminates in the dilated 'cloaca,' which receives the terminations of the urinary and generative organs.

The pancreas is large. The lymphatics and lacteals are fully developed. There are two equal-sized, symmetrical, thoracic ducts, which pour their contents respectively into the right and left subclavian veins.

Circulation.—The blood is somewhat hotter, as is the general temperature of the body, in Birds than in Mammalia. The heart is perfectly four-chambered, and placed exactly in the median line ; the aorta arches over the root of the right lung.

Respiration.—Every means are employed to render the respiration of birds rapid and complete. The lungs are large and perfectly cellular throughout ; the bronchial tubes branch dichotomously throughout their remotest parts, and even pass right through them, by two large apertures, conducting the air into the general cavity of the abdomen, which is not yet separated from the thorax by anything but a rudimentary diaphragm (except in the Apteryx and a few others). Fibrous septa divide the cavity into loculi. The air is even conveyed into the bones, which are extensively hollowed out for the purpose. In birds of flight it is the upper extremities alone which are pneumatic ; while in cursorial birds the air only reaches the lower extremities.

Expiration is effected by means of the sternum being forcibly drawn towards the vertebral column by muscular action ;

inspiration is effected by the resiliency of the sternum enabling it to return to its original position, and so expand the chest. The trachea of birds is interesting. Most birds have a double larynx, one situated at the top of the trachea in the position of the ordinary mammalian larynx, the other at the lower end of the trachea, where it is about to bifurcate into the two bronchi. When the latter exists it is the chief seat of vocalisation. It is formed by modified rings and half-rings of the trachea. It is largest in the duck tribe.

Kidneys.—The kidneys are large, formed of cortical substance only, and lodged in recesses in the lumbar vertebræ; the ureters terminate in the common cloaca. There is no urinary bladder.

Nervous System.—The cerebral hemispheres (prosencephalon) are much the largest elements of the encephalon, and partially conceal the olfactory lobes (rhinencephalon) in front, and the optic lobes (mesencephalon) behind. The medulla still supports a cerebellum, which consists of little more than a median lobe; small appendages are, however, present, in which are recognised the flocculi or pneumogastric lobules. There is no fornix, or corpus callosum. The optic lobes are not only inferior but lateral in position. This is peculiar to the class.

The cranial nerves have the same origin and distribution as in mammalia. The fifth sends twigs to the very tip of the sensitive beak.

Senses.

Touch.—This sense resides chiefly in the bill and tongue. The soft corium of some birds' feet is a tactile organ. The feathers are cutaneous growths, and formed upon a vascular papilla at the bottom of a deep pit; they are composed of epidermic cells, variously shaped. Each feather consists of a quill or barrel, and a vane or beard, which is again formed of barbs and barbules. The barbules, from contiguous barbs, hook into each other like the latch of a door into its catch, so as to present an even and resisting surface to the opposition of the air.

Taste.—This is imperfectly developed. The tongue is covered with thick, horny papillæ. It is more perfect in the Parrot tribe than in other birds.

Smell.—This sense is not very highly developed. Even in Vultures, in which it is more perfect than in most birds, it is now known that it is not by scent, but by sight, that they detect their prey. The turbinated bones, however, are present and somewhat convoluted. The nostrils are variously situated, generally upon the upper mandible ; large and open in most birds, they are small in Herons, and are absent in the Pelicans. The posterior nares open into the pharynx frequently by a single instead of a double aperture : such is the case with the Cormorants. The olfactory nerves leave the cranium by a single aperture, except in the Apteryx.

Hearing.—An external, middle, and an internal ear are now present for the first time. The external ear consists of a meatus only, there being as yet no pinna. The middle ear communicates by a large Eustachian tube with the pharynx, and by large mastoid cells with the cranium ; these cells often pass from one side to the other. There is only one ossicle present, called the *columella.* The internal ear consist of vestibule, semicircular canals, and cochlea. The vestibule is well developed ; the canals are large ; the cochlea is a bent, but not yet a spiral tube ; it is, however, divided by a median *lamina spiralis* into a scala vestibuli and scala tympani.

Sight.—This sense is perfectly developed. In addition to the ordinary tunics and humours, a singular vasculo-pigmentary structure is developed within the eye of birds, which passes from the entrance of the optic nerve towards the circumference of the lens. This is called the *marsupium* or *pecten* ; its use is probably to absorb super-abundant rays of light. The nocturnal Apteryx does not possess this structure. The lens is variously shaped ; flat in the high-soaring birds of prey, it becomes much more spherical in the aquatic birds, and almost completely circular in the owl. The sclerotic is often strengthened by imbricated bony plates. Birds possess three eyelids ; the lower eyelid is longer than the upper, and is freely movable. The third or nictitating membrane is lodged in the inner canthus. It is swept across the eye by the action of two muscles placed at the back of the eyeball, called the *pyramidalis* and *quadratus* muscles ; the former ends in a tendon, which passes through the other like a string through the top of a bag, and becomes attached to the lower corner of the membrana nictitans. There are two glands in connection with the eye ; the lachrymal gland, situated in its ordinary position, beneath the external angular process of the frontal bone, and the Harderian gland, situated behind the conjunctiva at the nasal angle of the orbit. The iris of birds contains striped as well as unstriped muscular fibre.

CHAPTER XXXIII.

General Characters of Mammalia.

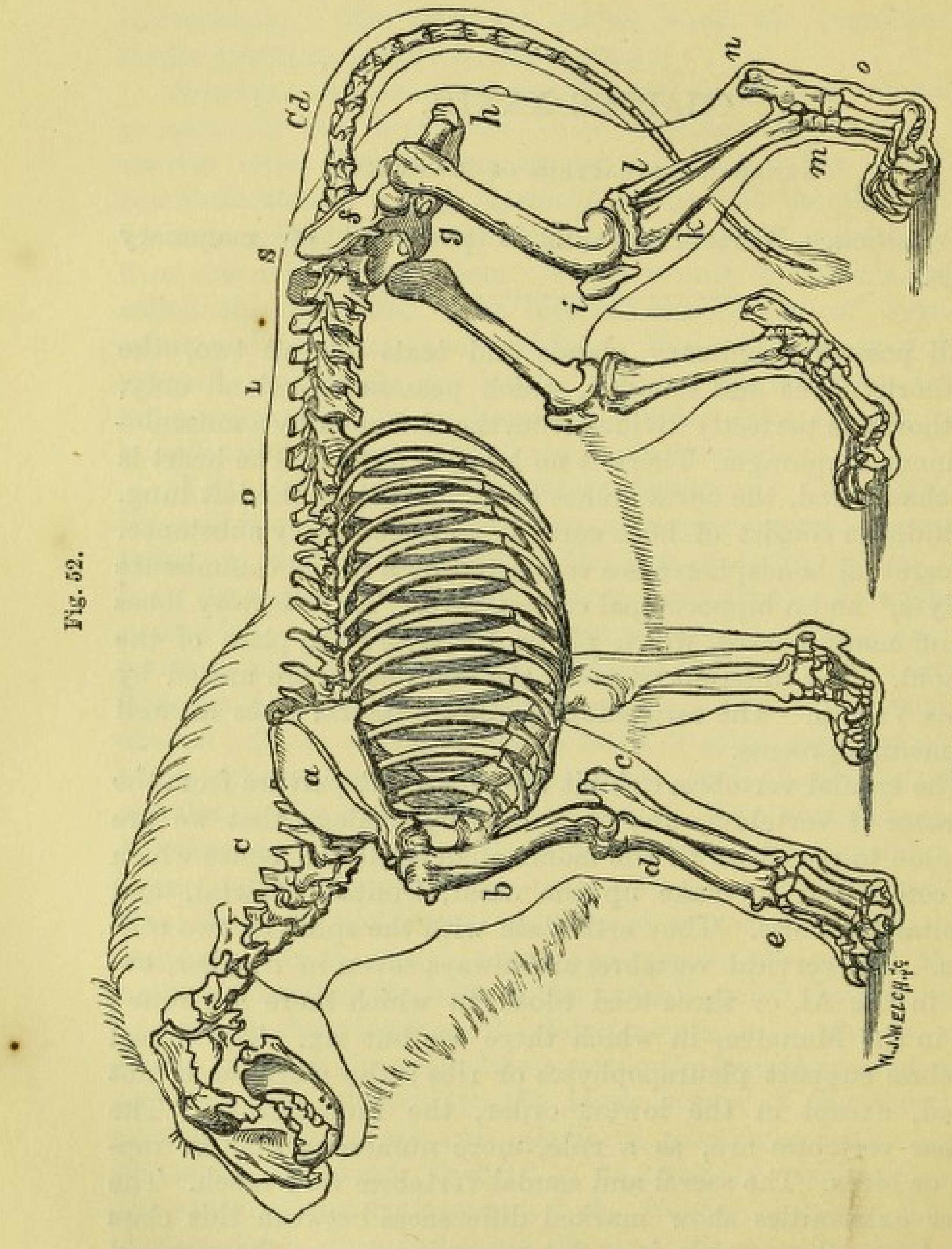
Definition.— Vertebrate animals possessed of mammary glands.

All possess mammary glands and teats except two, the Ornithorhynchus and Echidna, which possess the gland only. The thorax is perfectly divided from the abdomen by a musculo-tendinous diaphragm. There is no inferior larynx. The heart is four-chambered, the aorta arches over the root of the left lung. The kidneys consist of both cortical and medullary substance. The cerebral hemispheres are connected by a round commissure or 'lyra,' and a hippocampal commissure. The olfactory lobes give off many nerves, which pierce the cribriform plate of the ethmoid. The different parts of the encephalon are united by a pons Varolii. The cerebellum possesses lateral lobes as well as a median process.

The cranial vertebræ exhibit the greatest departure from the character of vertebræ, and it is only by analogy that we are still able to recognise in the mammalian skull the bones which are considered to make up the nasal, frontal, parietal, and occipital vertebræ. They articulate with the spine by two condyles. The cervical vertebræ are always seven in number, except in the Ai, or three-toed Sloth, in which there are nine; and in the Manatee, in which there are but six. The dorsal vertebræ support pleurapophyses or ribs; the sternum is not keeled, except in the lowest order, the Monotremes. The lumbar vertebræ are, as a rule, more numerous than in reptiles or birds. The sacral and caudal vertebræ vary much. The upper extremities show marked differences between this class and Aves—the scapula is a flat expanded bone: the coracoid is, except in Monotremata, merely a process of the scapula: the clavicles are not always present.

Skeleton of Mammals.—Not so dense as that of birds, but denser than that of fishes, *e.g.* the bones of man contain

Fig. 52.



SKELETON OF FELIS LEO.

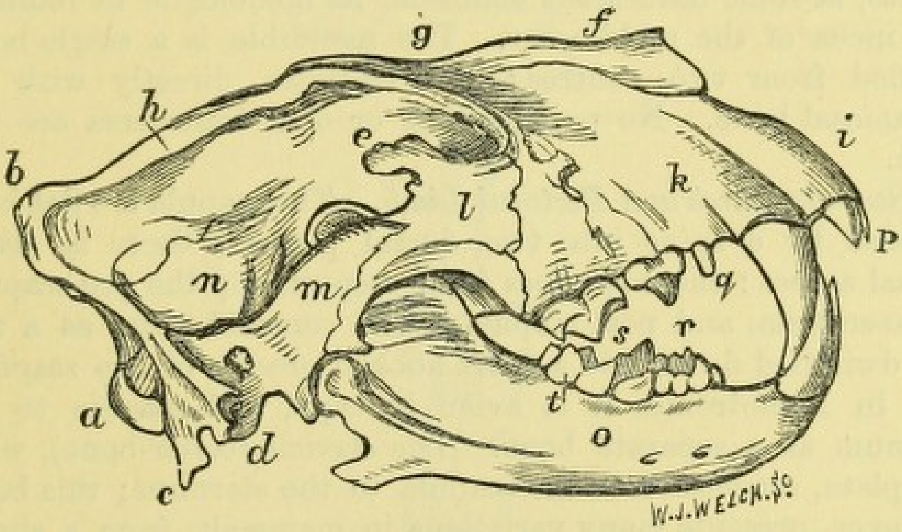
C. Cervical vertebræ. D. Dorsal vertebræ. L. Lumbar vertebræ. S. Sacral vertebræ. C. *d.* Caudal vertebræ. *a.* Scapula. *b.* Humerus. *c.* Ulna. *d.* Radius. *e.* Metacarpus and phalanges. *f.* Ilium. *g.* Femur. *h.* Ischium. *i.* Patella. *k.* Tibia. *l.* Fibula. *m.* Tarsus. *n.* Os calcis. *o.* Metatarsus and phalanges.

68·97 parts of earth, and 31·03 of animal matter. We have to glance at the condition of the cervical, dorsal, lumbar, caudal, and cranial vertebræ.

The *cervical vertebræ* are as a rule freely movable, and provided with neural, but no hæmal arches. The parapophyses and diapophyses enclose a foramen for the lodgment of the vertebral artery.

Trunk *vertebræ* vary in number from eleven to twenty-four. Pleurapophyses (ribs) join hæmapophyses (costal cartilages), which are never ossified, except pathologically in age. The last three or four ribs do not join the sternum, and are called

Fig. 53.



SKULL OF LION.

a. Exoccipital. *b.* Supraoccipital. *c.* Paroccipital. *d.* Mastoid. *e.* Postfrontal. *f.* Nasal. *g.* Frontal. *h.* Parietal. *i.* Premaxillary. *k.* Maxillary. *l.* Malar. *m.* Squamosal. *n.* Tympanic. *o.* Dentary. *p.* Incisor teeth. *q.* Premolar. *r*, *s*, and *t.* Molars.

'vertebral,' 'free,' or 'floating' ribs. The sternum is keeled in the Monotremata alone; in all other mammals it is flat. It consists of a *præ-sternum* (manubrium), *meso-sternum* (gladiolus), and *xiphi-sternum* (ensiform cartilage). The latter does not support ribs.

Lumbar vertebræ vary in number from two to nine; the neural spines are short and strong, as are also the parapophyses, so that free movement is enjoyed by the loins.

Sacral Vertebræ.—Absent in Cetacea, except Sirenia, which has one *sacral vertebra*; all other Mammalia possess them: as a rule implacental mammals have two, and placental mammals four sacral vertebræ. Some of the Primates, including man, have five.

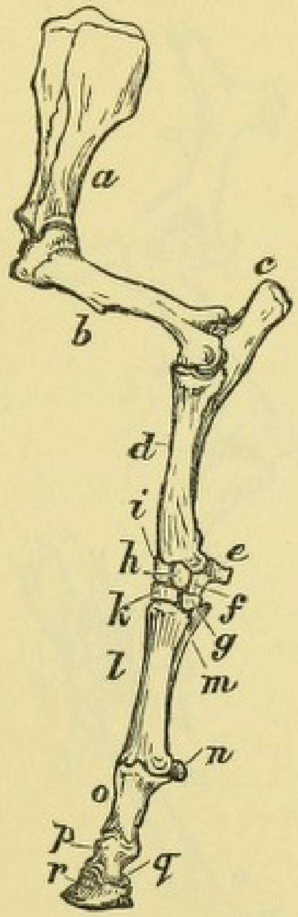
Caudal vertebræ vary from four to forty, and dwindle towards the tip of the tail, until nothing but the centrum remains.

Skull.—Bones of skull heavy, and skull as a rule comparatively large. The cranial walls often composed of two tables, an outer, somewhat yielding, an inner extremely dense or vitreous, with an intervening cellular structure or diplöe. Some mammals, as *e.g.* the elephant, have their skulls hollowed out into large air-spaces, so that they are not so massive as they look. In all, the occipital bone articulates with the atlas by two condyles, which are formed by the exoccipitals. There is no parasphenoid. The pre-sphenoid and basi-sphenoid are ossified from distinct centres. There is no os quadratum, unless, as some naturalists maintain, its homologue be found in the incus of the middle ear. The mandible is a single bone, ossified from two centres; it articulates directly with the squamosal bone. No post-frontals or ossa transversa are met with.

Scapular Arch and Pectoral Limb.—The scapula is a flat bone divided by a spine into two dorsal planes; there is also a dorsal aspect: these surfaces form respectively the pre-scapula, meso-scapula, and post-scapula. The coracoid bone as a rule has dwindled down into a short hooked process of the scapula; but in Monotremes it is avian in type, and reaches to the sternum as a separate bone. The clavicle (collar-bone), when complete, reaches from the scapula to the sternum; this bone, however, presents many variations in mammals, from a simple spicula to a well-developed bone. As to the upper limb itself, if we take a monodactyle mammal, as *e.g.* a horse, in which the limbs present their simplest form, we recognise a humerus, a radius, with which has coalesced the usually separate ulna; to these succeed a cluster of ossicles or carpal bones; and these are succeeded by a metacarpal bone and three terminal phalanges, which together form the digits. In mammals which possess more than one digit, this single digit corresponds to the middle finger.

Pelvic Arch and Hind Limb.—The ilium when present, homologue of the scapula, is a flat bone, and articulates with the sacral vertebræ. The ischium, homologue of the coracoid, forms the under part of the pelvis, and, for the most part, surrounds the obturator foramen. The pubis, homologue of the clavicle, forms the front part of the pelvis, and unites with its fellow anteriorly at the symphysis pubis. All three bones assist in forming the acetabulum, and all three are long distinctly recognisable as separate bones. Taking the horse still as the type, we first find a strong femur, which articulates with an equally strong tibia, to which is joined the usually separate fibula ; the ossicles which succeed form the *tarsal bones*, but the joint here formed is technically termed the knee ; to these bones a single metatarsal bone succeeds, called the cannon-bone ;

Fig. 54.



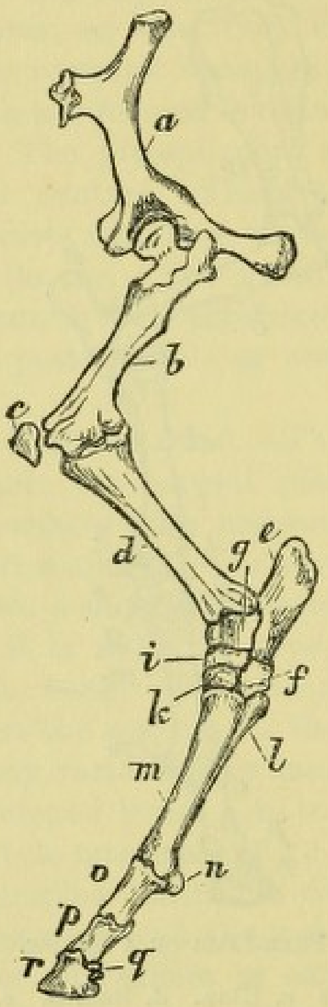
FORE-LIMB OF A HORSE.

a. Scapula. *b*. Humerus *c*. Ulna. *d*. Radius. *e*. Pisiform. *f*. Cuneiform. *g*. Unciform. *h*. Lunare. *i*. Scaphoid. *k*. Magnum (these bones form the wrist or carpus, but together are commonly called knee). *l*. Middle metacarpal, or cannon bone. *m*. Third metacarpal or splint bone. *n*. Sesamoid bone. *o*. Greater pastern, or first phalanx. *p*. Lesser Pastern, or second phalanx. *r*. Coffin bone or ungual phalanx, covered with nail or hoof. *q*. Coronary bone.

a triple row of phalanges, called respectively the greater pastern, lesser pastern, and coffin bone follow the cannon bone in a linear series. Below the tarsal bones, the ossicles of both fore and hind limbs have received the same names. These digits correspond to the middle toe in those mammals which possess more than one digit.

The Exoskeleton and its Appendages.—Mammals are generally covered with a hairy skin. The most important modifications, as *e.g.* in the Armadillos, will be referred to in describing the mammalian orders. Teeth are generally present, occasionally absent. When mammals only possess one set—which being shed are not replaced by a second—they are called *monophyodont*; when the milk set is succeeded by a permanent set they are

Fig. 55.



HIND-LIMB OF A HORSE.

a. Pelvis. *b*. Femur. *c*. Patella. *d*. Tibia. *e*. Os calcis. *f*. Cuboid. *g*. Astragulus. *i*. Scaphoid. *k*. Ecto-cuneiform. *l*. Third Metatarsal bone. *m*. Middle Metatarsal bone. *n*. Sesamoid bone. *o*, *p*, and *r*. First, second, and third Phalanges. *q*. Coronary bone.

called *diphyodont*. In some, however, we find an intermediate dentition which has been termed *heterodont*. In the human subject there are thirty-two permanent teeth, which have received the following names: the central teeth, placed on the maxillæ, are the *incisors*; the next tooth in the maxilla is the *canine*; the next two are *premolars;* the last three *true molars* in each half; the names of the lower teeth correspond to the upper. The same nomenclature is employed in describing the teeth of all diphyodont and heterodont mammals. The dental formula always refers to the permanent set when the animal is diphyodont.

CHAPTER XXXIV.

Classification of Mammalia.

Mammalia are divided into different orders by different naturalists ; but, broadly speaking, one of two principles is followed, the one of a somewhat artificial character, founded on anatomical and psychological cerebral differences, and the other of a more natural, but, as yet, not sufficiently worked out character, founded on certain reproductive characteristics. The one is called the *cerebral*, and the other the *reproductive organs* classification.

In contrasting the two it will be perceived that while the orders in the two schemes are, for the most part, similar, yet that their relationship to other orders is often widely different ; *e.g.*, the classification founded on the reproductive organs brings the Bat tribe, the Insectivores, and the smooth-brained Rodents, into the same sub-class with Man, while the anatomical classification places the three above-mentioned orders together, but in a subclass far below even that of the Carnivora. On the whole, the anatomical division groups the orders more naturally than the other system, in spite of its own more artificial character. This, however, is probably due to imperfections in our knowledge of the natural system (as we must regard the latter), rather than to any inherent inferiority in the plan itself.

We may, indeed, safely infer that both classifications are but tentative and temporary, and will eventually give way to a classification which will embrace the entire Animal Kingdom, and which, like one of the systems it supersedes, will be founded upon the nature of the reproductive organs ; not, however, on any one particular, but upon a general review of all the characteristics.

The classifications of Mammalia at present in vogue are, however, the following :—

CEREBRAL CLASSIFICATION.

Sub-Class		Orders	Type
Sub-Class 1. Archencephala		Bimana	Man
Sub-Class 2. Gyrencephala	Unguiculata	Quadrumana .	Ape
		Carnivora . .	Lion Bear
	Ungulata . .	Artiodactyla .	Hog Ruminants
		Perissodactyla .	Horse Rhinoceros
		Proboscidia . .	Elephant
	Mutilata . .	Cetacea . . .	Whale
		Sirenia . . .	Dugong
Sub-Class 3. Lissencephala		Bruta	Sloth Armadillo
		Cheiroptera . .	Bat
		Insectivora . .	Mole Shrew
		Rodentia . . .	Rats Hare
Sub-Class 4. Lyencephala		Marsupialia . .	Kangaroo
		Monotremata .	Ornitho- rhynchus

In reference to the above, it must be remarked that the marsupials and monotremes, which are distinguished as Lyencephala, or loose-brained, from the supposition that they do not possess a corpus callosum, are now said to be furnished with that organ, so that their separation from the Lissencephala is unwarranted. Again, the elevation of man to a distinct sub-class, Archencephala, however pleasing to our vanity, or correct in a purely psychological point of view, cannot be regarded as anatomically accurate, as there are not sufficient purely anatomical grounds for separating him from the rest of the Gyrencephala. With these exceptions, however, the classification must be regarded as, for a time, a very good one.

PLACENTAL OR REPRODUCTIVE ORGANS CLASSIFICATION.

Sub-Class		Orders	Type of Placenta
Sub-Class 1. Monodelphia,	Deciduata	Primates	Discoid
		Carnivora	Zonular
		Insectivora	Discoid
		Cheiroptera	Discoid
		Rodentia	Discoid
		Proboscidia	Zonular ?
	Doubtful	Sirenia	——— ?
	Non-Deciduata	Artiodactyla	Diffuse in Hogs, Cotyledonous in Ruminants
		Perissodactyla	Diffuse
		Cetacea	Diffuse
		Bruta	
Sub-Class 2. Didelphia . . .		Marsupialia	Aplacental
Sub-Class 3. Ornithodelphia . .		Monotremata	Aplacental

This classification, in associating such totally dissimilar orders as Proboscidia and Primates, Carnivora and Cheiroptera, is manifestly imperfect, and even misleading; but, for reasons given above, we may rationally suppose that these errors are due to an imperfect and partial view of the question rather than to any radical flaw in the system itself.

Professor Huxley adopts the above classification and divides the entire sub-kingdom of Vertebrata as follows :—

1. Mammalia; 2. Sauropsida (*σαύρα*, a lizard; *ὄψις*, look, aspect), which includes both Aves and Reptilia; and 3. Ichthyopsida (*ἰχθύς*, a fish, *ὄψις*), which includes Amphibia and Pisces.

1. **Mammalia** he arranges, according to the placental characters of the female, into those possessing a discoidal deciduate placenta, those possessing a zonary deciduate placenta, those possessing a non-deciduate placenta, and those not possessing a placenta at all. Each of these sub-classes contains the following orders :—

Mammalia possessing a discoidal deciduate placenta :—

1. Primates.
    - *α*. Anthropidæ (Bimana).
    - *β*. Simiadæ (Quadrumana).
    - *γ*. Lemuridæ (Quadrumana).
2. Insectivora.
3. Cheiroptera.
4. Rodentia.

Mammalia possessing a zonary deciduate placenta :—

1. Carnivora.
2. Proboscidea.
3. Hyracoidea (consisting of the single genus Hyrax).

Mammalia possessing a non-deciduate placenta :—

1. Ungulata.
2. Cetacea.
3. Sirenia.
4. Edenta.

Mammalia not possessing a placenta at all :—

1. Marsupialia.
2. Monotremata.

2. **Sauropsida** (*Aves et Reptilia*).

Aves he divides into three orders.

1. Saururæ (*σαύρα*, a lizard; *οὐρά*, a tail): only contains the fossil Archeopteryx.

2. Ratitæ (*ratis*, a raft): include birds whose sterna are not keeled, *e.g.* Ostriches.
3. Carinatæ (*carina*, a keel): birds whose sterna are keeled.

Reptilia he divides into four living and five extinct orders.

1. Crocodilia,
2. Lacertilia,
3. Ophidia,
4. Chelonia,

} living.

1. Ichthyosauria (ἰχθύς, a fish; σαύρα),
2. Plesiosauria (πλησίος, near; σαύρα),
3. Dicynodontia (δι-, two; κύων, a dog; ὀδούς, a tooth),
4. Pterosauria (πτέρον, a wing; σαύρα),
5. Dinosauria (δεινός, terrible; σαύρα),

} extinct.

3. **Ichthyopsida** (*Amphibia et Pisces*).

Amphibia he divides into four orders.

1. Urodela (οὐρά, a tail; δῆλος, manifest): Proteus, Newts, &c., &c.
2. Batrachia (βάτραχος, a frog): Frogs and Toads.
3. Gymnophiona (γυμνός, naked; ὄφις, a snake): Cecilia, &c., &c.
4. Labyrinthodontia (labyrinth; ὀδούς, a tooth): extinct.

Pisces into six orders.

1. Dipnoi (δι-, double; πνοή, breath): Lepidosiren, &c.
2. Elasmo-branchii (ἔλασμα, a thin plate; βράγχια, gills), Sharks, &c.
3. Ganoidei (γάνος, brightness): Lepidosteus, Polypterus.
4. Teleostei (τέλειος, perfect; ὀστέον, a bone): most living fish.
5. Marsipo-branchii (μάρσιπος, a pouch): Lampreys and Hags.
6. Pharyngo-branchii: Amphioxus.

CHAPTER XXXV.

Class V. Mammalia—Description of Separate Orders.

1. **Monotremata** possess a coracoid bone, which, like the same bone in birds, extends from the sternum to the scapula. The sternum is keeled. They are edentulous, or possess simple calcified teeth. A common cloaca receives the openings of the digestive canal and the urino-generative organs. There is a supplementary tarsal bone, or spur, in the male, which is perforated. Only two genera are found in this order, and both are Australian—the Duck-Mole, and the spiny Ant-eater, or Echidna.

Monotremata are implacental, and the young are born in a very immature condition. There are marsupial bones on the female pubes, which are really ossifications of the internal tendon of the external oblique muscle; these bones do not support a marsupium or pouch. The angle of the jaw is not inflected.

The Duck Mole, or *Ornithorhynchus paradoxus*, appears to be the connecting link between Mammals and Birds, as the Pterodactylus is the link between the Birds and Reptiles. This singular animal is shaped like, and somewhat resembles, a large mole, but its jaws are prolonged in the shape of a broad flattened bill like the beak of a duck, bearing the nostrils upon its upper surface. The five claws are all connected by webbing, like the feet of a natatorial bird, and each of its hinder feet carries a spur, which communicates with a poison gland placed behind the tarsus. There are also sternal osseous ribs, as in Birds. The mode in which the young Platypus is first nourished is unknown, but it is conjectured that the horny bill is preceded by a suctorial mouth, which is probably placed in communication with the orifices of the lacteal ducts, which open upon a plane surface, there being no nipples.

The *Echidna* resembles a large hedgehog, and is furnished like the Platypus, with an edentulous duck-like bill. The feet are five-clawed, but they are not webbed. The lacteal ducts open into a pouch-like involution of the integument: like Ornithorhynchus, it has no teats. Both the Echidna and the Ornithorhynchus are crepuscular or nocturnal in their habits, as is the case with so many of the Australian Fauna.

Order 2. **Marsupialia** comprise Kangaroos, Phalangers, Wombats, and Opossums. They inhabit Australia, with its neighbouring islands, and North America. They are named from the fact that they possess pouch-like bags attached to the so-called marsupial bones, which are processes of the pubic bones. In the female the pouch is inverted, and serves as a receptacle for the offspring. Each oviduct of the female leads into a perfectly distinct uterus, which opens into a separate vagina, which is also the passage for the urine. This double condition of the uterus gives the name of didelphia (δις-, two ; δελφύς, the womb) to the order. That this is scarcely a sufficient circumstance upon which to ground the placental classification above referred to, is seen in the fact, that even the human uterus occasionally presents this peculiarity. Such a reversion is evidence enough that this double condition of the marsupial uterus does not constitute a broad line of demarcation between them and other mammals. In the male the vasa deferentia open into a cloaca common to the urinary and generative secretions, but which is distinct from the passage for the fæces. The two passages, however, open together, and are guarded by a common sphincter. The testes are never retained in the abdomen, as in Monotremata, but are suspended in a scrotum placed anteriorly to the penis. Marsupials are implacental. The young are born in a very immature condition, and are conveyed by the tongue of the mother from the uterus to the marsupium, where they are glued, by a viscid secretion, to one of the nipples in that pouch. Here the young marsupial lives and grows, the milk being squeezed into its throat by the action of a sphincter muscle, which surrounds the gland itself, and therefore is not sucked. The epiglottis rises like a plug to be fixed into the posterior nares, so that the young creature is saved from any risk of being choked by the milk going the 'wrong way.' The cranium is composed of bones joined by suture. The coracoid bone is not a separate bone as in Monotremata, but is appended as a process to the scapula. Teeth always present, but only one set are ever cut.

The *Wombat* is a nocturnal, phytophagous marsupial, inhabiting Australia; it resembles a gigantic guinea-pig, with short stumpy legs, no apparent neck, no visible tail, and a very fat round body covered with soft, light brown hair. Dental formula: $i\,\frac{1-1}{1-1}\;c\,\frac{0-0}{0-0}\;pm\,\frac{1-1}{1-1}\;m\,\frac{4-4}{4-4}=24.$

The *Kangaroo* is also a phytophagous Australian marsupial, distinguished by the great length and strength of the hinder limbs, which are the chief means of locomotion, and which in the 'old man kangaroo' assist the tail in preserving an equilibrium in the sitting position. The fore limbs are very slight, and are used chiefly as organs of prehension. Dental formula: $i\,\frac{3-3}{3-3}\,c\,\frac{0-0}{0-0}\,pm\,\frac{1-1}{1-1}\,m\,\frac{4-4}{4-4}=32.$

The *Phalanger*, *Koala*, or *Native Sloth*, is an arboreal phytophagous Australian marsupial, about the size of a large fox. There are strong claws, two in front and two behind. They are called Phalangers, because the second and third toes on the hind limb are united together. The Flying Phalanger, or Petaurus, performs extraordinary leaps or short flights by the aid of an integumental cloak, which the animal can extend between the fore and hind limbs.

Some of the marsupials, termed consequently *Entomophaga*, are not herbivorous, but carnivorous in their habits. They comprise the Bandicoots (*Peramelidæ*) and banded Ant-eater (*Myrmecobius*) of Australia, and the Opossums of America (*Didelphidæ*).

The *Opossums* are arboreal, and feed on birds, small animals, and fruit; they have prehensile hind feet and prehensile tails. The marsupium is often rudimentary, the young being early carried upon the mother's back, where they keep their hold by twining their long prehensile tails around her body. Dental formula: $i\,\frac{5-5}{5-5}\,c\,\frac{1-1}{1-1}\,pm\,\frac{3-3}{3-3}\,m\,\frac{4-4}{4-4}=52.$

The *Thylacine* is another carnivorous marsupial, about the size of a collie-dog, inhabiting Tasmania; and the low-looking, broad-headed, fierce little Tasmanian Devil (*Dasyurus ursinus*) is another.

Order 3. **Rodentia** are distinguished from all other Mammalia by their peculiar dentition. There are two long curved incisors in each jaw, which serve for gnawing the barks of trees or other substances, on which the rodent feeds. Their anterior surface only is covered with enamel; the rest of the tooth is composed of softer dentine, which, wearing down sooner than the enamel, always leaves a sharp chisel-like edge to the tooth. They are always growing from a persistent vascular papilla situated at their base. The incisors are separated from the molars by a wide interval or diastema. The former are called from their chisel-like edge *dentes scalparii*. Rodentia possess five toes on each foot. The orbits are not separated from the temporal fossæ. Clavicles rudimentary. The hind legs of many, *e.g.* the Hare and Jerboa, are much longer and more powerful than the fore legs; they are used in locomotion, and remind one of the legs of the kangaroo. Intestine is long and complex. Testes descend into a scrotum during the rutting season, and then ascend again. Many hibernate. Most rodents are small creatures, but the Capybara attains a length of four feet. This order also contains Hares, Cavies, Porcupines, Beavers, Rats, Jerboas, Dormice, Squirrels, and Agoutis. The Beaver, in spite of its smooth unconvoluted brain, shows much ingenuity in the construction of its dwelling-places, felling logs with its teeth, placing them as dams across a stream, arranging others to form a shelter from the wet, and welding them together by a mortar of mud, which it lays on with its flat, scaly, trowel-like tail. The Flying-Squirrel (*Pteromys*) possesses an integumental cloak, like that of the *Petaurus*, stretching between the fore and hind limbs, and endowing it with similar powers of leaping and taking short flights. The rodents are the most numerous of all the mammalian orders, containing upwards of thirty different genera. Dental formula: $i\,\frac{1-1}{1-1}\,c\,\frac{0-0}{0-0}\,m\,\frac{6-6}{6-6}$ or $\frac{2-2}{2-2}=28$ or 12.

Order 4. **Insectivora** are also distinguished by their dentition. In them we find incisors, canines, and molars. The latter are peculiar teeth, their summits being furnished with numerous cusps. 'They are unguiculate, plantigrade, and pentadactyle, and they have complete clavicles.' This is a very widely distributed order of small smooth-brained mammals. The Shrew, the Hedgehog, and the Mole are examples of the order. Like Rodentia, the Insectivora hybernate and possess testes, which periodically descend into a scrotum, and then re-ascend into the abdomen. They often burrow, and are nocturnal in their habits. The *Moles* burrow with their fore paws; the entire fore limb being immensely strong. The humerus is a short but broad and flattish bone, with extraordinary processes and juttings for the attachment of muscles. The palms of the claws are turned outwards. The tail is short or wanting. The optic nerves are really present, but are atrophied in age. Dental formula: $i\,\frac{3-3}{3-3}\,c\,\frac{1-1}{1-1}\,pm\,\frac{4-4}{4-4}\,m\,\frac{3-3}{3-3}=44.$

The Galeopithecidæ or Flying Lemurs are considered as somewhat 'aberrant insectivorous forms.' They differ from the other insectivora in having a 'patagium' or 'flying-membrane.' The limbs are elongated, and are connected together, and to the neck, trunk, and tail by the patagium, this membrane also uniting the digits of the posterior limbs. In these creatures the patagium is covered with hair on both sides. The dentition is somewhat peculiar, the outermost incisor teeth of the upper jaw being provided with double roots, this peculiarity not being known to exist elsewhere.

The *Sorex Etruscus*, one of the Shrews, is the smallest known mammal, only measuring $2\frac{1}{2}$ inches from snout to the tip of the tail. The *Hedgehogs* possess a spiny exoskeleton, covering the entire body, and lined with a plane of cutaneous muscular fibres, the platysma, which, contracting, pulls the prickly hide over the head and tail, and rolls the animal into a ball. Dental formula: $i\ \frac{3-3}{3-3}\ c\ \frac{1-1}{0-0}\ pm\ \frac{3-3}{3-3}\ m\ \frac{3-3}{3-3} = 38.$

Order 5. **Cheiroptera** (χείρ, a hand; πτερόν, a wing) are distinguished by the peculiar modification which their digits undergo; the latter, except the thumb, are immensely lengthened and provided with a membranous covering, which passes in a wing-like manner from the webbed phalanges to the lower extremities; the phalanges of the thumb are much shorter than the rest, and terminate in a hooked process, by means of which the animal clings to branches of trees or projecting parts of walls. The integumental cape is called, like that of the Flying Lemurs, the *patagium*; it envelopes the hinder part of the body, and stretches between the fore and hind limbs; it acts like an expanded umbrella, and enables the animal to take rapid and long-continued flights—the Bat is, indeed, the only true flying mammal. The external ear is very large, and copiously supplied with nerves, rendering it a most acutely sensitive organ of touch: the sense of hearing is also very highly developed. The Vampire Bat (*Phyllostoma spectrum*) has a curious leaf-like integumental expansion covering the nose. It has attained a very evil reputation from its supposed habit of attacking sleeping human beings and sucking their blood. The truth of this assertion, however, is doubtful. They are well known to attack cattle, but it is seldom, if ever, that they assail man. Upon the anterior surface of the stomach of these creatures is to be found a diverticulum or cæcal pouch communicating with the cavity of the viscus, and suggesting some analogy between it and the cæcal diverticula of the stomach of the blood-sucking leech. The phytophagous Bats comprise *inter alios*, the *Pteropus*, or Fox Bat, which is a fruit-eating bat, although it possesses a head almost exactly resembling a fox. Dental formula in insectivorous Bats is $i\ \frac{0-0}{0-0}$ or $\frac{1-1}{1-1}\ c\ \frac{1-1}{1-1}\ m\ \frac{3-3}{3-3} = 16$ or 20.

In frugivorous Bats it is $i\ \frac{2-2}{2-2}\ c\ \frac{1-1}{1-1}\ m\ \frac{6-6}{6-6} = 36.$

Order 6. **Bruta** (*Edentula*) are many of them perfectly edentulous ; others possess teeth, which, however, consist of dentine only, and are never replaced by a second set. They possess more ribs (twenty-three pairs) than other mammals. One species, the three-toed Sloth, has nine cervical vertebræ.

They are all provided with long strong claws, which serve them for weapons wherewith to dig up their insect food. The testes are abdominal. There is a common cloacal outlet.

All Bruta are monophyodont, if they possess teeth at all: the central incisors are never developed; and the canines rarely so. Clavicles generally present, but absent in Pangolins and Myrmecophaga.

A placenta is present during development. There are certain features which connect them somewhat closely with the Sauropsida, such, *e.g.*, as the convolutions of the trachea, the increased number of cervical vertebræ, the slowness of movement, and the shape and number of the ribs which are met with among the Sloths.

Bruta comprise Sloths, Pangolins, Ant-eaters, and Armadillos.

The *Sloths* (*Bradipodidæ*) are South American phytophagous Bruta, which pass their lives among the branches of the primeval forests, hanging by their powerful hooked claws back downwards from the boughs, and travelling in the same fashion, with ease and rapidity, from tree to tree. The *Unau*, or two-toed Sloth, is furnished with two toes upon each foot, all supplied with long, curved, strong claws: it also possesses twenty-three pairs of ribs. The *Ai*, or three-toed Sloth, has three short toes furnished with enormously strong curved claws, and sixteen pairs of ribs. The fore limbs are much larger than the hind limbs, and the fore and hind paws are articulated to the bones above at an oblique angle, so that when standing on all fours the animal cannot apply the soles of the feet to the ground, but shuffles along on their sides, as though suffering from talipes varus ; this, however, is the most advantageous angle for progression and for security when hanging, *more suo*, from the branches of trees. A remarkable *rete mirabile* is found in the axilla, which nourishes and sustains the muscles of the limbs during their long tonic contractions.

The *Armadillos* (*Dasypodidæ*) are South American insectivorous Bruta, with strong digging claws and clavicles. The molar teeth are very numerous, sometimes numbering 100, and the exoskeleton is very strong, forming a dense jointed coat of mail, which, however, leaves the middle of the back uncovered ; in fact, there are two large plates, one for the head and another for the hinder part of the body. The great fossil *Glyptodon* of the Pleistocene strata belongs to this group.

The *Ant-eaters* and *Pangolins*, the former confined to South America, and the latter found in Asia and Africa, are insectivorous Bruta of singular conformation. The great Ant-eater (*Myrmecophaga jubata*), of the size of a wolf, has a body covered with long hair, a large bushy tail, feet terminated with powerful digging claws, and a small head ending in a long bony snout, which is about four inches wide and a foot long. This edentulous snout contains a narrow muscular tongue, which can be protruded two feet beyond the tip of the snout, and being coated with a viscid secretion, serves to catch the insects (Termites, &c.) which form the food of the animal.

The *Pangolins* (*Manidæ*) are coated with an imbricated exoskeleton, in which they can wrap themselves like hedgehogs, by the contraction of a similarly fashioned platysma; they obtain their food like the Ant-eaters of South America, by digging up the nests of Ants with their strong claws.

The fossil Megatherium belongs to this group.

Order 7. **Sirenia** (*σειρην*, a siren or mermaid) are phytophagous. They possess molars as well as incisors, and develop both a temporary and a permanent set of teeth ; *i.e.* they are diphyodonts. The nostrils are situated on the top of the snout, and are beset with stiff bristles. They possess vesiculæ seminales, salivary glands, and a membrana nictitans, which Cetacea do not.

The Dugong and Manatee are illustrations of this order.

In the genus Manatis there are but six cervical vertebræ. In all, the mammæ are pectoral, whereas in the Cetacea they are inguinal.

They are adapted to an aquatic life, and have smooth india-rubber-like skins, and a powerful horizontally flattened integumental caudal fin. There are no hind limbs. There are no clavicles. The zygomatic arch is enormous. The heart is so deeply cleft at the apex as to give it the appearance of being double. Anterior limbs act as paddles. Dental formula of young Manatee : $i\ \frac{2-2}{2=2}\ m\frac{8-8}{8-8}=40$. They browse upon the sea-weed and fuci of the rivers and sea coasts, where they are found. The extinct Rhytine belonged to this order.

Order 8. **Cetacea** (*κῆτος*, *a whale*) are fish-like in form and habits. They are either edentulous or monophyodont, *i.e.* possess but one set of teeth. They are the largest of all living forms, and, next to the elephant, their brains are the heaviest known, weighing about five pounds. The nostrils are situated on the top of the head, and constitute the *blow-holes* or *spiracles.* The peculiarities of their respiration are described under the Physiology of Mammalia. This order includes the Whales and Dolphins. All possess a large horizontally flattened caudal fin.

The body is generally smooth and hairless, except on the lower lip. The testes are abdominal, and there are no vesiculæ seminales. No hind limbs or sacrum, but a small pelvis is present, which supports the penis or clitoris, and rudimentary femurs. No clavicles. The head is enormous, often forming half the entire bulk of the animal.

The *Balænidæ*, or whalebone Whales, are all toothless whales: in Balæna Mysticetus, however, we find rudimentary teeth in early fœtal life. They comprise the largest of all living creatures, the Greenland Whale, which is the Coryphæus of the group, attaining a length of sixty or seventy feet, a third of which is formed by the head. This enormous head is nearly all mouth, which leads to a comparatively small œsophagus. This is due to the fact that the monsters live on minute prey, small Pteropoda constituting the chief article of diet. The mouth is surrounded by vertical fringed plates of 'baleen,' or whalebone, which, sunk into the roof of the mouth by their base, have their free edges minutely fringed, and these fibres hanging close alongside one another, entangle the Mollusca on which the animal feeds.

The *Finners* belong to the Balænidæ, and are characterised by having a dorsal cutaneous fin, a furrowed skin, and very large fins or 'flippers.' The blubber of the Balænidæ is the subcutaneous fat, which exists in enormous quantities for the purpose of maintaining the animal heat during their protracted immersion in the Arctic seas.

The toothed Whales (*Odontoceti*) form another group of Cetacea, all of which possess a great many large conical teeth, implanted in alveoli and occupying the lower jaw. The teeth of the upper jaw are abortive, and do not cut the gum. The Sperm Whales are included in this division; the blubber in them is supplemented by a clear oil, which, removed from the body, hardens into spermaceti. The intestines also contain vast masses of a curious biliary secretion, known as ambergris, which is used in perfumery. The head is large and abruptly truncated, like the cutwater of some steamers; it occupies about a third of the entire animal, and is therefore sometimes as much as ten yards long. The nostrils are placed at the end of the muzzle. The *Physeteridæ*, as these Sperm Whales are called, swim in large societies or 'schools.' The males are much larger than the females.

Another group of Cetacea comprises the Dolphins, Narwhals, and Porpoises, and is known as *Delphinidæ*, all of which possess teeth (sometimes curiously modified) in both jaws. The Delphinidæ are less aberrant in shape than the other Cetacea, the head only forming about one-seventh of the entire animal. The blow-hole is single, and placed on the top of the head: it is generally transverse in direction, and lunate in shape. The common Porpoise (*Phocæna communis*) is by far the best known member of this group. The head is not so sharp as in Dolphins. The *Grampus* also belongs to this group. The Narwhal (*Monodon Monoceros*) is remarkable for its dentition. The lower jaw is destitute of teeth; the upper jaw of the male contains two abortive molars and two incisors, one of which, the left, is enormously developed to form a spiral 'rostrum' or tusk, which may be seven or eight feet in length. It is extremely hard, dense, and heavy; and so gigantic is the force with which the animal can wield it, that it has been found buried to a depth of four feet in a ship's side, having penetrated oak and iron in its passage. The females possess rudimentary teeth in the upper jaw, and occasionally develop a tusk like the male.

The right upper incisor is present, but only developed sufficiently to cut the gum.

The skull of Cetacea is remarkable, and differs from the skull of all other mammalia in the bony ear-capsule being separable from all the rest of the bones of the skull, and only connected to the cranium by ligament. These bones constitute the so-called 'ear-bones' of the whale.

The peculiarities in the circulation and respiration of Cetacea are referred to under the head of the Physiology of Mammalia.

The UNGULATA or hoofed mammals, which form the next sub-class, are all diphyodont in dentition, and possess large enamelled molars with broad crowns: they all have digits enclosed in a strong epidermic growth, the *hoof*. They contain three orders, *Proboscidia* or Pachydermata, *Artiodactyla* or Ruminantia, and *Perissodactyla* or Solidungula.

Order 9. **Proboscidia** comprise the Elephant and the extinct Mastodon, the Dinothere, and the Mammoth. Proboscidia are characterised by a peculiar dentition, and by a singular modification of the nose. There are no canine teeth, but the incisors are developed into *tusks*, which, in the Elephant, grow from the upper jaw; in the Dinothere they grow from the lower jaw; and in the Mastodon from both jaws. These incisors are associated with molars, of which there are not fewer than six on each side of both jaws. The nose is prolonged into a long, flexible, highly-sensitive, muscular *trunk*, in which Cuvier counted no less than 20,000 distinct muscles, which is terminated by a small prehensile appendage like a finger. They are pentadactyle. The testes are abdominal; the mammæ are pectoral. The dorsal vertebræ and ribs number about twenty, and the lumbar vertebræ about three. There are about four vertebræ in the sacrum, and about twenty in the tail. The bodies of the cervical vertebræ are very much flattened, reminding one of the condition of the vertebræ in Cetacea, and the neck is consequently short. The skull is very large, but contains very large loculi or spaces for air, which materially lighten the massive structure. The premaxillæ are large and the nasals small; the mandible forms a bifid curled projection at the symphysis. The super-occipital crest is high, affording attachment to the powerful muscles of the neck.

There are no clavicles. The scapula is shaped much as in Ruminants, and is placed vertically over the bones of the fore limb; the carpal bones and digits are short and massive; a very strong thick pad intervenes between the toes and the ground. The pelvis and pelvic limb very much resemble the scapular arch and fore limb. There is no round ligament in the acetabulum.

Dental formula – Elephant: $i\frac{1-1}{0-0}\ m\frac{2-2}{2-2}=10.$

" " Dinothere: $i\frac{0-0}{1-1}\ m\frac{2-2}{2-2}=10.$

" " Mastodon: $i\frac{1-1}{1-1}\ m\frac{2-2}{2-2}=12.$

The incisors always form tusks. The molars are very large and massive, with transverse plates of inflected enamel.

Order 10. **Perissodactyla** (περισσός, add; δάκτυλον, a finger) comprise the odd-toed Ungulata, whether the digits be one, as in the Horse, or three, as in the Rhinoceros. The dorso-lumbar vertebræ are numerous, but are never fewer than twenty-two. The femur possesses a third trochanter. If the specimen be horned, the horn is either single, or one horn is placed behind another, but always in the median line. The horns, when present, are always dermic growths. The alimentary canal is simple, but the cæcum is very large. Many of the Perissodactyla are fossil, *e.g.* Palæotherium, Hipparion, &c. It is now represented by the Horse, the Rhinoceros, the Tapir, and the little Hyrax.

The Horse, which with the Ass and Zebra forms the old order of Solidungula, has only a single perfect toe on each foot, coated with a nail called a hoof, so that the horse walks and runs not merely on its toes but on its nails.

Dental formula : $i\frac{3-3}{3-3}$ $c\frac{1-1}{1-1}$ $pm\frac{3-3}{3-3}$ $m\frac{3-3}{3-3}=40.$

The Limbs of Horses.—The scapular arch consists of a scapula alone, which is slung among the muscles of the back by the *levator anguli scapulæ* and *serratus magnus* muscles ; the scapula is placed at an angle both to the spine and to the fore limb, increasing the elasticity of the limb, and distributing the concussion when the Horse alights upon its fore feet ; the more this is the case the more *ragged hipped*, or *shouldered*, is the Horse. The scapula is a narrow bone, and has a small coracoid process and no acromion. The humerus is concealed in the muscles of the trunk, and is directed backwards from the scapula. The radius forms nearly the whole of the fore-arm, the ulna being very small and anchylosed to it. There are seven carpal bones —all, in fact, but the trapezium, being present; to these succeed the metacarpal bone of the third finger, and three phalanges, which are termed, from above downwards, the cannon bone, the greater and lesser pasterns, and the coffin bone. Small splint-like metacarpals from the second and fourth toes support this central one on either side, but do not reach the ground.

The pelvis, like the scapula, is elongated, and articulates with the spine and femur at a double angle. The femur is short, hidden in the muscles of the buttock, and furnished with a third trochanter. The tibia forms almost the whole of the leg ; the fibula being merely a small splint bone, which is lost about half-way down the leg. There are seven tarsal bones, and to these succeed a linear series of bones, which exactly correspond to the arrangement in the manus.

The Rhinoceros has three toes, on which it walks, upon each foot ; one, or two, dermic horns also are present. The nasal bones are very large.

Dental formula : $i\frac{2-2}{2-2}$ $m\frac{7-7}{7-7}=36.$

The Tapir has four toes on its fore feet, and three on its hind feet, a short snout, projecting nasal bones, and a short stumpy tail.

Dental formula : $i\frac{3-3}{3-3}$ $c\frac{1-1}{1-1}$ $m\frac{7-7}{6-6}=42.$

The Hyrax is a little animal of the size of a rabbit, found in Syria, with four toes on its fore feet, and three toes on its hind feet. There are upwards of thirty dorsi-lumbar vertebræ.

Dental formula : $i\frac{2-2}{2-2}$ $pm\frac{4-4}{4-4}$ $m\frac{3-3}{3-3}=36.$

By some authors this animal is elevated to a distinct order, the Hyracoidea. It is the *Coney* of Scripture.

The derm of all the Perissodactyla, but particularly that of the Rhinoscerida, is remarkably thick and tough, which gave the old name of Pachydermata to the group.

No order affords stronger evidence of the direct descent of one species or genus from another quite distinct one, than this order of Ungulata, the Horse being traced by a succession of the finest links, first to the three-toed *Hipparion*, and back from Hipparion to the *Anchitherium* of the Eocene strata, in whom not only were there three digits on each foot, but distinct and perfect fibulæ and ulnæ.

Order 11. **Artiodactyla** comprise the even-toed Ungulata. 'The digit answering to the third in the pentadactyle foot is unsymmetrical, and forms, with the fourth, a symmetrical pair.' The number of dorsal and lumbar vertebræ may each vary in different species, but added together they almost invariably number nineteen. The Artiodactyles are not always horned, but if they possess these appendages, they are always double, and are supported by a bony core ; they are never placed in the median line.

Most Artiodactyla possess a complex stomach, and a comparatively small cæcum. Many species are extinct, *e.g.* Microtherium, Anoplotherium, &c., but it is also very numerously represented at the present day.

Most Artiodactyla do not develop all the teeth, some, as a rule, being abortive ; but the typical dental formula is—

$$i\frac{0-0}{3-3}\quad c\frac{0-0}{1-1}\quad pm\frac{3-3}{3-3}\quad m\frac{3-3}{3-3}=32.$$

Artiodactyla comprise ruminating and non-ruminating animals. The Ruminantia contain five families—Camelidæ, Moschidæ, Cervidæ, Camelopardalidæ, and Cavicorniæ. The Non-Ruminantia contain three families—Hippopotamidæ, Suidæ, and Anoplotheridæ.

The *Camelidæ* include Camels, Llamas, and Alpacas. They only possess two functionally active toes on each foot, which are partially encased in a horny hoof and rest upon an elastic pad or cushion, which is homologous to the *frog* of a horse's foot. There are no horns. The dentition is peculiar, there being two canine-like upper incisors in addition to two true upper canines. The hump is a dermic or rather subdermic growth, composed of fat and cellular tissue. The paunch of the Camel is divided into deep pits, with muscular sides and tops ; the latter contracting converts these pits into barrels, which, being filled with water before they start on a journey, can be *tapped* at will during the trip.

The *Moschidæ*, or Musk Deers, are peculiar in possessing canine teeth in both jaws, the upper ones in the male forming tusks ; in the second and fifth digits of both fore and hind feet being complete ; and in the anchylosis of nearly all the tarsal bones. The red blood-cells of the Musk Deer are smaller than those of any other vertebrate, only measuring $\frac{1}{12325}$th of an inch in diameter. The well-known perfume from which these animals derive their name, is secreted by an abdominal gland, which the male alone possesses.

The *Cervidæ* include all the true Deer. All the males possess dermic horns, which are shed in the autumn, and grow rapidly in the spring ; very rarely, as *e.g.* in the Reindeer, the female develops antlers as well as the male.

Growth of Antlers.—The horns of Stags are always shed once a year ; they are developed from the frontal bones, and during growth are covered by an extension of the integument called the *velvet* ; the external carotid arteries, and all the cutaneous vessels increase vastly in size, and yield a rich supply of blood to the growing antler ; when growth is completed, a horny circumferential rim just above the frontal bone, and called the *burr*, becomes more pronounced ; the growth of this burr extends inwards until it becomes perfectly dense and impervious to vessels ; the velvet, or skin, then dies and peels off, leaving the bony antlers bare and hard ; the supply of blood becomes smaller and smaller, and by-and-by the vascular connection between the antlers and the frontal bone is quite suppressed, and the horns then drop off. The piece of bone between the burr and the frontal bone is called the *pedicel.* The various parts of the antlers of a stag have received the following names. The main stem is the *beam*, the branches are the *tynes*, and the branchlets the *snags.* The first tyne is the *brow tyne*, the second is the *bez tyne*, the third is the *royal*, and the cluster at the *crown* are the *sur-royals.* The Stags only develop a perfect set in the course of several years ; thus a one-year-old Red Deer is called a *brocket*, and only develops the *beam*, such antlers being called *dags* ; the next year the Deer is a *spayal*, and grows *brow tynes* ; the next year the Deer, called a *staggard*, develops *bez tynes* and *royals* ; and it is not until the fifth year, when the animal is called a *stag*, that the antlers are completed. The corresponding names of the Fallow Deer, are first year a *pricket*, second a *sorel*, third a *sore*, fourth a *buck*, and in the seventh year, when the antlers are complete, a *full-headed buck.* The Elk and extinct Irish Elk belonged to this family, and developed antlers of enormous magnitude. All the Cervidæ possess large glands beneath the eyes lodged in *tear pits*, which pour out a copious watery secretion, especially under excitement.

The *Camelopardalidæ* include the Giraffes, and are known by possessing two permanent stumpy frontal horns. The neck, long as it is, only consists of seven cervical vertebræ: the tongue practically increases the length of the neck, being used as an organ of prehension; it can be protruded for a foot or more beyond the mouth, and wound around the branches of trees.

The *Cavicorniæ* (*Bovidæ*) include Oxen, Sheep, Goats, and Antelopes. Males always, females generally, possess permanent horns, containing an interior core, which rises as an exostosis from the os frontis, the entire core being coated with horn; the horns are often beautifully twisted and curled.

Dental formula : $i\frac{0-0}{3-3}\quad c\frac{0-0}{1-1}\quad m\frac{6-6}{6-6}=32.$

Turning now to the non-ruminating division of Artiodactyla, we find the *Hippopotamidæ*, *Suidæ*, and *Anoplotheridæ*. The *Hippopotamus* is a huge unwieldy mammal, nocturnal in its habits, phytophagous in diet, and aquatic in its locomotion. The mouth contains a huge ragged row of teeth, some serving to rake the aquatic herbage together, others to cut it, and others to grind and masticate it.

Dental formula : $i\frac{2-2}{2-2}\quad c\frac{1-1}{1-1}\quad m\frac{7-7}{7-7}=40.$ The lower canines form the great shovelling tusks.

The *Suidæ*, or Pigs, are recognised by having only two functional toes on each foot, and by their dentition—the lower or upper canines curling upwards into a formidable tusk, which may remain erect as in the Wild Boar; or as in the *Babyrussa*, where they are the upper canine teeth, they may turn round and round like a French horn, until they may even penetrate the skull of the owner, much as a Fakir's hand is pierced by the finger nails of his long-clenched fist.

Dental formula : $i\frac{2-2}{2-2}\quad c\frac{1-1}{1-1}\quad m\frac{3-3}{3-3}$ or $m\frac{7-7}{7-7}=24$ or 40.

The *Anoplotheridæ* form a distinct group of entirely fossil non-ruminating Artiodactyla found in the lower Tertiary strata, and having the dental formula : $i\frac{3-3}{3-3}\quad c\frac{1-1}{1-1}\quad m\frac{7-7}{7-7}=44.$ They were slender creatures with long tails, and feet with cleft hoofs.

Order 12. **Carnivora**, the first order of the Unguiculata (*unguis*, a nail) or nailed mammals, comprise the great banditti of nature in the fierce beasts of prey. They are distinguished by the possession of retractile or non-retractile claws, and their dentition. There are both milk and permanent teeth, for which the formula is as follows : — incisors, $\frac{3-3}{3-3}$; canines, $\frac{1-1}{1-1}$;

molars, $\frac{3-3}{3-3}$. The canine teeth are always very largely developed, and serve as powerful lethal weapons. The clavicles are rudimentary, or quite absent. They are subdivided, according to the character of their limbs, into *Pinnigrades* (*pinna*, a feather ; *gradior*, to walk), which includes the Seal and Walrus tribe ; *Plantigrades* (*planta*, the sole of the foot), which includes the Bears, and all flat-footed Carnivora ; and, lastly, the *Digitigrades*, or Carnivora that walk on their toes, which subdivision includes the Cat and Dog tribe. The mammæ are abdominal, and the placenta is zonary.

Skeleton of Carnivora.—Cervical vertebræ seven. The transverse processes of the atlas and axis are very long, affording attachment to powerful muscles, which move the head in tearing prey.

Dorsal vertebræ thirteen to sixteen, with the spinous processes of the upper vertebræ projecting backwards, and those of the lower projecting forwards. *Lumbar vertebræ* four to seven ; spinous processes short and broad. *Sacral vertebræ* four to seven. *Caudal vertebræ* six to twenty-three.

Skull. — Supra-occipital crest very high, and largely developed for attachment of muscles ; but the posterior surface of skull is small, the chief length being due to the large size of maxillæ and premaxillæ. The implantation of the canine teeth is indicated externally by a very large and prominent buttress of bone. Orbits not separated from temporal fossæ. Turbinals large and convoluted in association with the high development of the sense of smell. The zygomatic arch stands out very boldly from the skull, leaving a deep temporal fossa for the origin of the immensely powerful *temporalis* or *crotalis* muscle. The mandible is large and powerful, with a very small angle. The cerebrum is separated from the cerebellum by a bony tentorium. The mastoid bone forms a large tympanic bulla, which increases the vibrations of sound. All carnivora have two sets of teeth, all of which are coated with enamel.

Appendicular Skeleton.—Scapula flat and broad, divided into two almost equal parts by the spine. Humerus, a long strong bone, a good deal bowed, so as to aid in distributing concussions. Radius and ulna both present : radius the larger bone of the two, and placed directly *in front* of ulna. Carpal bones small, eight in number. Five metacarpals and five digits, placed nearly vertically. The strong curved claws are kept hidden when at rest—'le main de fer avec le gant de velour'—being retracted by an elastic ligament which is connected with their dorsal aspect ; but when brought into use they are protruded with tremendous force by the *flexor longus digitorum*. They are placed on one side of the ungual phalanges, and do not linearly succeed them.

Pelvis is short, but strong and compact. Femur a long and very powerful bone. Tibia and fibula both perfect ; the fibula being placed directly behind the tibia. Seven tarsal bones. Os calcis forms a very prominent keel. Five metatarsals and digits, placed vertically as in fore paw. Carnivora comprise Pinnigrada, Plantigrada, and Digitigrada.

The *Pinnigrada* comprise the Seals and Walruses. The fore feet are webbed and form paddles. The hind feet are at the end of the body ; they are close together, enveloped in folds of integument, and in action closely simulate the action of the screw of a steamship. The body is fish-like, and they possess no external ears, except in the case of *Otaria*. As in Cetacea, no lachrymal glands are present. They live on fish. Walruses differ from true Seals in possessing two long tusk-like and nearly vertical upper canine teeth, by which the animal drags itself on to the beach and defends itself if attacked.

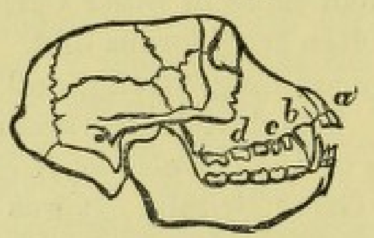
The *Plantigrada* comprise the Bears. The molar teeth of Plantigrades are flatter than those of other Carnivora in correlation with the mixed and often frugivorous diet. The tongue of Bears is smooth. The claws are long, strong, and non-retractile ; they are used in digging. The clavicles are absent. The kidneys are lobulated. Remains of the Cave-Bear, *Urso spelæus*, are freely found in France and Great Britain. It was a powerful beast, as large as the American Grizzly, and is found associated with human remains in the so-called Neolithic and Palæolithic periods of Prehistoric man. Racoons, Bears, Badgers, Kinkajous, and Coatis are instances of Plantigrade Carnivores.

The *Digitigrada* comprise the fierce and powerful Cats, Polecats, Ferrets, Weasels, Dogs, Hyænas, Jackals, Otters, &c.

Some of the Digitigrada, *e.g.* Weasels, possess sebaceous glands near the anus, called *anal glands*, which secrete an offensive fluid, under cover of which the animal escapes when pursued. This anal gland is not homologous with the coccygeal gland of man. The irides of many Digitigrades are highly contractile, almost completely occluding the pupil at times. The Hyænas possess four toes on each foot; the rest are pentadactyle. The *Felidæ*, or Cats, are the most typical of Digitigrada. The head is almost round, the canines very large, and the masseter and temporal muscles immensely powerful. Dental formula : $i\,\frac{3-3}{3-3}\;c\,\frac{1-1}{1-1}\;pm\,\frac{3-3}{3-3}\;m\,\frac{1-1}{1-1}=32$. The tongue is furnished with a rasp composed of horny recurved papillæ, which assist the teeth in lacerating the flesh of prey. The dental formula of the dog differs from that of the Cats, and is as follows : $i\frac{3-3}{3-3}$ $c\frac{1-1}{1-1}$ $pm\frac{4-4}{4-4}$ $m\frac{2-2}{3-3}=42$. The first molar of the lower jaw, and the fourth premolar of the upper jaw are large teeth with trenchant cutting edges ; they are called the *sectorial* or *carnassial* teeth.

Order 13. **Quadrumana** are distinguished from all other mammals by the peculiar modification of their limbs, which are terminated by hands. This invariably applies to the hinder limbs, not invariably to the fore limbs. In every quadrumanous animal or Monkey, the hind limb is terminated by a hand ; in every bimanous animal by a foot. The essential feature of a hand is the possession of an opposable digit, or thumb. The dental formula is the same as that of man, or else there are three premolars in each jaw instead of two. The summits of the teeth are never on the same level. Quadrumana are subdivided, according to the position of their nostrils, into—1.

Fig. 56.



SKULL OF A MONKEY.
(*Cercopithecus ruber*), showing the facial angle and character of dentition.
a. Incisors. *b.* Canine. *c.* Premolars. *d.* Molars.

Strepsirrhines, or monkeys with twisted nostrils, such as the Lemurs and Aye-ayes ; 2. Platyrrhines, or monkeys with simple sub-terminal nostrils, such as the Spider Monkeys ; and 3. Catarrhines, or monkeys with oblique nostrils approximating below, separating above, such as the Gorilla and the Chimpanzee. All Quadrumana are clothed with hair. They all possess perfect clavicles, pectoral mammæ, and organs of generation and reproduction similar to those of man.

Strepsirrhinæ are the lowest of the monkey tribe. They comprise the true Lemurs, Loris, and the Aye-aye, and inhabit Madagascar, Africa, and the contiguous islands. The pollex is very short and feeble, scarcely opposable to the other digits. They are frugivorous in their diet. The second digit of the hind foot is furnished with a long claw.

Dental formula : $i\ \frac{3-3}{3-3}\ pm\ \frac{3-3}{3-3}\ m\ \frac{3-3}{3-3}=36.$

Platyrrhinæ are either South American or New World monkeys with prehensile tails. Arboreal in habits. No cheek pouches. The Howling Monkey (*Mycetes*), one of the Platyrrhines, has a curious modification of the larynx in the shape of a bony drum attached to the hyoid bone, with which it produces the most piercing and discordant shrieks. The pollex in this animal is not opposable. The occipital foramen is still placed quite at the back of the skull, as in all animals that go on all fours, and the cranium is very narrow. They are generally very small animals. Dental formula of the Marmoset is $i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;pm\frac{3-3}{3-3}\;m\,\frac{2-2}{2-2}=32.$ Dental formula of other Platyrrhines : $i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;pm\frac{3-3}{3-3}\;m\,\frac{3-3}{3-3}=36.$

Catarrhinæ include the highest or anthropoid apes of the Old World. They are all (with the exception of Colobus) strictly four-thumbed, and the dental formula is, as in Man: $i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;pm\frac{2-2}{2-2}\;m\,\frac{3-3}{3-3}=32.$ The tail is not prehensile, and is often absent or quite rudimentary. Cheek pouches present in the lower but not in the higher apes. *Baboons* have a rudimentary tail and a gluteal region devoid of hair. Many possess 'natal callosities,' which are often, as in the Mandrill, brilliantly coloured, probably by sexual selection. Facial angle is 30°.[1] The anthropoid Apes do not possess cheek pouches or natal callosities, and the facial angle amounts to 40°.

The canine teeth are large, and the gluteal region is covered with hair. The arms are long ; reaching in the Chimpanzee to the middle of the tibia when hung down.

Order 14. **Bimana** contains but one genus and one species, Homo. The distinguishing characteristics of this order are these : the summits of the teeth form a nearly perfect level, and are not separated from each other by an interval ; the dental formula is as follows : $i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;pm\frac{2-2}{2-2}\;m\,\frac{3-3}{3-3} = 32.$ The great toe is not opposable to the other digits. The arms are shorter than the legs ; the reverse of this is the case in the Quadrumana. The facial angle of Man varies from 90° to 120°.

The foot is planted upon the ground by the entire length of the sole, and the whole arrangements of the frame are obviously intended to subserve the erect position. The chief differences

[1] The facial angle is calculated by drawing converging lines towards the anterior nares from the external auditory meatus, and from the glabella, or space between the supra-orbital ridges.

between Man and the highest Simiæ, such as the Chimpanzee and the Gorilla, are the following:

Skeleton. Skull.—The skull of Man is both absolutely and relatively to the face larger than in the Anthropomorpha ; the superciliary ridges are smaller : there are no distinct premaxillæ at birth ; the jaws are smaller, but a chin is present ; there is no diastema, or interval between the teeth; there is a nasal spine; the foramen magnum is situated more anteriorly; there is scarcely any perceptible crest upon the occipital bone.

Vertebral Column.—The cervical spinous processes are short and generally bifurcated; there are twelve dorsal and five lumbar vertebræ, whereas in the Gorilla there are thirteen dorsal and four lumbar ; the entire column is much more sinuously bent than in the Anthropomorpha.

Shoulder and Pelvic Girdles and Upper and Lower Limbs.—The humerus and bones of forearm are relatively shorter ; the pollex reaches the middle of the first phalanx of the index finger. The pelvis is broader and shallower ; the femur is absolutely and relatively longer; the fibula descends lower than the tibia ; the foot is relatively shorter and broader ; the second digit is the longest ; the great toe is never opposable to the other digits, but is much larger than in the Anthropomorpha.

Muscular System.—Man possesses a *peroneus tertius*, an *extensor primi internodii pollicis*, a tibial origin for the *soleus*, and an entire calcaneal origin for the *flexor brevis digitorum*; none of these are met with in the highest Apes.

Nervous System.—The absolutely and relatively greater size and complexity of the brain: in Man, too, the brain and brain case are asymmetrical, in the Simiæ they are symmetrical.

From this it will be gathered that the mere morphological differences between Man and Monkey are very slight, and that, before we can assign him his true place in Nature, we must regard him not only morphologically but physiologically and psychologically; for the possession of a power of abstract reasoning, of framing hopes, of forming and employing language, are his, equally with the possession of a subglobular skull and an erect attitude, and are not to be lost sight of in considering his relations to other animals, any more than the features of pure anatomical distinctions.

Bimana are divisible into men with woolly hair, *Ulotrichi*, and into men with smooth hair, *Leiotrichi*. The former comprise the Negroes of the African races and the Negritos of the Malay Archipelago; the latter include the rest of the human race. The chief differences between man and man consist in the shape and size of the skull, and the size and complexity of the brain. Taking a Bushman as one type and a European as another, we find the Bushman characterised by a comparatively low facial angle of about 90°, by projecting jaws (*prognathism*), by smallness and comparatively greater breadth of cranium ; we also find that the skull is bilaterally quite symmetrical, and the convolutions of the brain almost perfectly so ; the brain, too, is relatively smaller, and the convolutions both fewer and less deep. The skull of the European, on the other hand, has a facial angle of about 120°, vertical jaws (*orthognathism*), a large and comparatively long cranium; we find also that the skull is bilaterally asymmetrical, and the two hemispheres of the brain notably dissimilar ; the convolutions, too, are much more numerous and extend deeper into the substance of the brain.

CHAPTER XXXVI.

Physiology of Mammalia.

Prehension, Deglutition, and Digestion.—All Mammalia use their lips as organs of prehension, which are assisted in Bimana, Quadrumana, Rodentia, and Marsupialia, by their fore limbs. The Carnivora tear their prey with their claws, but do not use them as prehensile organs. The proboscis of the Elephant, the snout of the Tapir, the long muscular and viscid-tipped tongue of the Ant-Eater, and the long tongue of the Giraffe, are special prehensile organs.

The teeth of Mammalia differ widely in the different orders, both in their number, shape, and size. The Echidna and the Myrmecophaga, or true Ant-eater, have no teeth. The Narwhal has but two, one of which is always rudimentary. The Dolphin has 190. The Elephant generally has six, which are succeeded by a second set, which do not grow from below, as in Man, but from behind, and as they advance they push out the previous tooth; by this contrivance the few-toothed Elephant is never left without sufficient grinders. The typical number of teeth in the Rodentia is twenty, in Quadrumana forty-four, in Bimana thirty-two. The teeth of the Cetacea are very peculiar; the Cachalot Whale and Dolphin tribe have a large number of conical teeth, composed of dentine, lodged in wide sockets; the Balæna mysticetus (Whalebone Whale) presents, instead of true teeth, a series of plates of whalebone which are ranged in rows along the upper jaw; from these plates depend a long fringe of finely-divided whalebone threads which act as a sieve. The huge animal swims through the Polar seas with his mouth wide open, and receives into his gigantic maw thousands of little mollusca, which abound in those regions, the Clio Borealis being the most abundant of all; they are entangled in the meshes of whalebone, and swallowed. These constitute the chief food of this leviathan of the deep.

The salivary glands are developed much as in man throughout the Mammalian class, except in the Cetacea, where neither salivary nor lachrymal glands exist, and in the Ant-Eater, in which animal they are enormously developed, and pour their secretion into a special cervical reservoir, called a *salivary bladder*.

There are three distinct types of *stomach* met with amongst Mammalia—the simple, the compound, and the complex stomach. The *simple* stomach consists of a single cavity, presenting a cardiac recess or pouch at the œsophageal end, and narrowing to a pyloric valve at the duodenal end ; throughout it is lined by an epithelium which secretes gastric juice ; this form of stomach is met with in Bimana, Quadrumana, Carnivora, and in some Cheiroptera, Insectivora, Bruta, Cetacea, Marsupialia, and Monotremata.

The *compound* stomach is a variety of the former ; the single cavity being partially divided by folds into two or more spaces ; the histological elements of the mucous membrane are, however, the same throughout. This form of stomach is met with in some Cheiroptera, in the Manis or Pangolin amongst Bruta, in the Kangaroo, in the carnivorous Cetacea, in some Rodents, and still more typically in the Sloths. The Ant-eater possesses a sort of crop, to which succeeds a stomach with such thick muscular walls as to recall the gizzard of a bird ; a resemblance that is still further borne out by the Ant-eater's stomach frequently containing gravel, which, like the stones met with in a bird's gizzard, serve the purpose of teeth.

The *complex* stomach is peculiar to Ruminants, with the exception of Balænoptera Rostra, and is the most interesting of all. In these animals the stomach is divided into four distinct cavities : (1) the paunch, or rumen, or ingluvies, or panse ; (2) the reticulum, or honeycomb, or bonnet ; (3) the omasum, manyplies, psalterium, or feuillet ; and (4) the abomasum, reed, or rennet.

The *paunch* is by far the largest of all the cavities in the adult animal, to which it serves as a storehouse for the herbage ; in the young Ruminants the fourth stomach is, on the contrary, larger than the paunch. The *paunch* is lined with a dense white squamous epithelium. Its office is to store the food, and mix it with the water which it contains ; its secretion has scarcely any digestive function. In the Camels, Llamas, and Dromedaries, the paunch contains a number of pits, whose mouths are closed by muscular rims, and which serve as water-butts for storing up fluid when the animal is going a long, arid journey. There are several of these butts in the stomach of the Camel ; they measure about eighteen inches in length, by six inches in breadth, and three inches in depth. They are subdivided by muscular partitions into many distinct cavities.

The *reticulum* is very much smaller, and presents an appearance like a honeycomb, whence its name. The polygonal spaces into which it is divided serve to fashion the food into small round pellets, which are one by one regurgitated into the animal's mouth, there to undergo a second mastication; this constitutes rumination. A certain amount of the fluid parts of the food are absorbed by the veins of the reticulum. The mucous membrane is papillated. A groove leads along the upper border of the reticulum direct from the œsophagus to the third stomach, the manyplies; this can be converted into a complete canal, by the muscular action of the walls of the reticulum, and so the food must then pass direct from the œsophagus into the manyplies.

The *manyplies* is of an elongated form, and has its mucous membrane arranged in parallel longitudinal folds, like the leaves of a book—whence its French name, 'le feuillet.' Small folds alternate with larger ones. There are some forty in the sheep, and about eighty in the ox. The mucous membrane is villous. Further digestion of the soluble saccharine and fluid portions of the food goes on here, before it is passed on into the rennet, or fourth stomach.

The *rennet* is the true digestive stomach, and homologue of the single stomach of man. It is the largest cavity of all except the paunch. The mucous membrane is highly vascular, and is thrown into longitudinal rugæ. The *rennet* contains the stomach tubes which secrete the gastric juice. It is here that the albuminous principles of the food are extracted and absorbed by the veins.

In all Mammalia a pyloric valve is present; and all, except Cetacea and a few Bruta and Cheiroptera, possess a distinction between large and small intestines; these exceptional animals do not exhibit any such distinction, nor do they possess an ileocæcal valve. The digestive canal is almost invariably longer in the herbivorous than in the carnivorous Mammals, *e.g.* the canal is as thirty to one of the entire length of the animal in the sheep, and as five to one in the cat and dog. A cæcum generally exists, and is developed in relation to the kind of diet; in flesh-feeding Mammalia it is comparatively small, or even absent, while it is very large in the vegetable-feeders. In the Horse it is three times as large as the stomach.

Man, Apes, Gibbons, and the little Wombat are the only Mammals possessed of a vermiform appendix; which evolution must teach us to regard in the light of a relic of a former condition when a double cæcum existed.

Circulation.—In all Mammals the heart consists of four distinct chambers: two auricles, and two ventricles which form a right and left side. The right side is the venous, the left the arterial. The right auricle receives the impure blood from the entire body, transmits it to the right ventricle, which pours it into the lungs, whence it is returned by the pulmonary veins to the left auricle, which transmits it to the left ventricle ; the aorta leading from this cavity carries the blood over the whole body ; the left side of the heart is thus engaged with the *systemic* circulation, the right with the *pulmonic* circulation. In Man and the higher Apes the heart inclines to the left side, in the rest of Mammalia it is in the median line. In the lower Mammalia the branches from the arch of the aorta are symmetrical, in all the higher Mammals they are unsymmetrical. The brachial artery in the Cat tribe passes through a foramen in the humerus above the inner condyle, to protect it from pressure ; a similar arrangement is met with in the artery of the coffin-bone in the Horse. When a large artery breaks up into a number of branches, all of considerable calibre, which freely inosculate with each other, a 'rete mirabile' is formed ; such an arrangement must manifestly delay the rapidity of the current of blood and equalise the pressure in the passage of blood through a part ; it is met with in the axillary arteries of Sloths, the internal carotid arteries of Ruminants, and the aortic and thoracic intercostals of Cetacea. In regard to the venous system, Man and all higher, and many of the lower Mammalia only possess one superior vena cava ; in Rodentia and Pachydermata there are two. In the Cetacea, venous as well as arterial plexuses exist, and serve as reservoirs for the impure blood during the protracted immersions of the animal.

In all Mammals except the Camel, in which they are oval, the blood discs are circular.

Respiration.—All Mammalia possess a diaphragm. In all except the Horse, Elephant, and most Cetacea, the lungs are divided into lobes, not exceeding three on the left, and five on the right side. In the exceptions named the lungs are not lobed. The only peculiar respiration is that of the Cetacea. The nostrils or *spiracles* in these fish-like Mammals are placed on the top of the head, and lead directly down to the pharynx, the top of which is surrounded by a strong sphincter muscle, which keeps it closed except when the whale 'blows.' The soft palate is prolonged to a considerable extent, so as to form a strong musculo-cartilaginous plug, which perfectly blocks up the passage from the mouth into the pharynx and larynx ; by this means the animal can swim about with its head under water, and its mouth wide open, and yet never be in danger of any water getting into the air-passages. After the air that the animal has breathed has become too impure for further use, the whale rises to the surface, and closing its mouth, it forces the water against the plug of the soft palate and drives it out, pumping the water into large cavities which surround the sides of the spiracle ; the top of the pharnyx contracts, the muscular summit of the spiracle relaxes, the muscular walls themselves contract and force the water violently from the spiracle into the air ; in other words, she 'blows.' When all the water is expelled, a fresh supply of air is taken in, and when a sufficient quantity is received, the leviathan dives down again 'full fathoms five.'

Kidneys.—The kidneys always consists of a cortical and medullary portion. In all Mammalia the kidneys are at first lobulated, and this condition persists in many of the class, particularly in the Bears, Otters, Seals, and some Cetacea, and to a less extent in the Ox.

Nervous System.—The *proscencephalon* (or cerebral hemispheres) now forms by far the largest portion of the brain, more or less overlapping the *rhinencephalon* in front, and the *mesencephalon* behind. The mesencephalon (or optic lobes) is no longer *bigeminal*, but constitutes the *quadrigeminal* bodies. A pons Varolii unites the various parts of the brain. The cerebellum consists of lateral hemispheres as well as a median vermiform process. These characters apply to all Mammalia. Monotremata, Marsupialia, Rodentia, Insectivora, Cheiroptera, and Bruta possess smooth unconvoluted brains.

The remaining Mammalian orders all possess brains more or less convoluted ; and this increase of surface, and consequently of grey matter, we invariably find associated with an increase of intelligence. The main difference between the brains of Bimana and Quadrumana lies in the greater complexity of Man's brain, the greater depth of the sulci, and greater amount of grey matter ; both are, however, developed on one common plan, and both possess a hippocampus major, and posterior cornu, in the lateral ventricles, which formerly were supposed to be confined to the human brain.

SENSES.

Touch.—Tactile corpuscles, which are the special seats of the sense of touch, abound in the lips of nearly all Mammalia ; they are also abundant in the hands of Bimana, which are the most perfect of all tactile instruments ; in the hands and feet of Quadrumana, in the snouts of the Tapir, the Pig, and the Rhinoceros, in the tip of the Elephant's trunk, in the general integument of Cetacea, in the base of the whiskers or *vibrissæ* in the Cat tribe, and at the tip of the prehensile tail of some Monkeys. The wings of Bats are also abundantly supplied with nerves and tactile corpuscles, and constitute a very perfect instrument of touch.

Taste.—The tongue is the seat of the sense of taste in all Mammalia except the Cetacea, which are probably devoid of this sense altogether. Bears possess two or three small accessory tongues. The glossopharyngeal nerve, which is distributed chiefly to the circumvallate papillæ at the back of the tongue, is the special nerve of taste. Secondary papillæ are present on all the papillæ of the tongue ; and in Carnivora these secondary papillæ become much lengthened and recurved, and serve to rasp the flesh off the bones. The long tongue of the Anteater, which can be protruded for sixteen or eighteen inches, is composed of circular muscular fibres, which elongate it, and of longitudinal muscular fibres, which shorten it.

Smell.—This sense is present in all Mammalia except Cetacea. Mammalia possess not only anterior and posterior nares, but a nose, made up of cartilages, ligaments, and muscles. This is enormously developed in the Elephant, forming the trunk. The cribriform plate of the ethmoid bone is perforated by several apertures instead of by one or two, as in the other vertebrate classes. The turbinated bones are three in number, and are all much convoluted, so as to increase the sentient surface ; and many of the neighbouring bones often contain hollow spaces or sinuses. In those animals, such as the Dog, which possess the faculty of scent, we find the turbinal bones rolled upon themselves to a very considerable extent, forming the 'labyrinth.' In many Cetacea the olfactory lobes and nerves are exceedingly small, and in the Dolphins and Porpoises they are absolutely wanting.

Hearing.—All Mammalia except Cetacea, Seals, Moles, Duck-Moles, and Armadillos, possess a pinna, as well as an external meatus. In those animals, such as the Bats, in which the sense is very acute, the pinna is very extensive. The tympanic cavity is always traversed by four ossicles, a malleus, incus, stapes, and os orbiculare, which are variously shaped. In the Whale the tympanum is separable from the rest of the organ of hearing, and constitutes a large shell-like bone, called the 'ear-bone.' A cochlea, forming from one-and-a-half to five turns, is always present, as are also a vestibule and three semicircular canals.

Sight.—The tunics and humours are the same as in Man. Nocturnal Mammals have comparatively large eyes. The Mole possesses extremely small eyes, and was said not to possess any optic nerves: they have, however, been recently discovered by Mr. Perrin. In Cetacea, as in Fishes, the sclerotic is immensely thickened, and enables the eyeballs to sustain the great pressure to which they are subject during their profound dives.

All Mammals except Cetacea possess lachrymal glands and eyelids; the true Cetacea possess only a *membrana nictitans.* Ruminants possess a large gland, called the *Harderian gland*, which assists the lachrymal gland in moistening the eyeball; it is situated at the inner canthus of the eye.

The muscles of the eye are the same, and supplied in the same way, as those in Man; but in addition to the four recti and two oblique muscles, there is usually a funnel-shaped muscle, called the *choanoid* muscle, interposed between the recti and the optic nerve. The contraction of this muscle serves to protrude the eyeball.

Nearly all Mammalia, except Bimana, Quadrumana, Bruta, and Monotremata, have a portion of the choroid lined by a pigment layer of metallic lustre, situated at the bottom of the eyeball, called the *tapetum lucidum.* It serves the purpose of a concave reflector, and illumines the eyes of the animals, which possess it, in the dusk.

CHAPTER XXXVII.

Organs of Generation and Mode of Reproduction amongst the Oviparous Vertebrata.

Fishes.—The ovary, called the *roe*, and the testicle, called the *milt*, both situated against the vertebral column, occupy a large extent of the thoracico-abdominal cavity. In the osseous Fishes, the countless myriads of ova, forming not merely the germs of future races, but serving as food for many of the present, are extruded from the ovary by a canal, situated immediately behind the anus, and in front of the urinary canal. These ova are impregnated externally to the body of the female by the semen of the male, which is emitted loosely into the water, and coming into contact with them vivifies them.

In the cartilaginous Fishes, the ova either pass from the ovary into the general cavity of the abdomen, whence they escape by two apertures, as in the eel, or, rupturing the ovarian capsule, they pass into distinct oviducts. In the highest of the Chondropteri, *e.g.* the Shark, impregnation takes place internally: the male firmly holding the female during coitus by means of two processes shaped somewhat like long boots, called 'claspers.'

Amphibia.—The ovaries and testes are situated, as they are in the whole of the oviparous tribes, in the lumbar region. Their contents are poured into a cloacal opening, common to themselves and the urinary and digestive organs. The male frog holds his spouse in a close embrace during the whole period of oviposition, and impregnates the ova during the period of their extrusion from the body of the female.

Reptiles.—The female possesses two oviducts, which terminate in a common cloaca. The male is provided with an intromittent organ. In Ophidia the penis consists of two separate bodies (corpora cavernosa), deeply grooved along their upper surface, along which groove the semen trickles. In Chelonia the corpora cavernosa, separate at first, unite to form an organ of considerable size. Impregnation takes place internally.

Birds.—The ovaries of the female are held to the vertebral column by folds of peritoneum. The *right* ovary and oviduct is always atrophied, so that it is the *left* alone which produces ova. The oviduct, which succeeds to the ovary, opens into a common cloaca ; it is nearly straight, except during sexual excitement, when it presents three principal curves ; the upper expanded part, which first receives the ovum, is called the *infundibulum*, the narrow contracted portion below constitutes the *isthmus*, and the wide and straighter portion near the termination is incorrectly called the *uterus*. The epithelium lining the oviduct differs in each of these situations, and in each the ovum obtains a fresh covering ; first, the *white of the egg*, next the *membrana putaminis*, and lastly, in the uterus, the *calcareous shell*.

The testes of the male are situated in the lumbar region, and increase very remarkably in size during the breeding season. Male birds that pass an aërial or arboreal existence only possess two sensitive papillæ, which are merely capable of juxtaposition ; but aquatic birds and the ostrich possess very perfect intromittent organs, in which both corpora cavernosa and a corpus spongiosum are easily distinguishable.

The ovum is composed of the following parts, which are essentially similar to the structure of the mammalian ovum. The entire ovum is contained in a delicate transparent membrane, the *vitelline membrane*, corresponding to the mammalian zona pellucida, parent of the future chorion ; within this membrane the *yelk* is situated, composed of a yellow oleaginous material with a number of granules. Upon the surface of the yelk we find another little membranus sac, called the *cicatricula* or *blastoderm* ; this is opaque, and contains within its interior the germ of the future animal. This germ presents the appearance of a minute transparent vesicle, and is called the *vesicle of Purkinje*, or the *germinal vesicle*. The egg of the bird and the egg of the lower Vertebrata are like each other in all essential respects; in shape, the reptilian egg is always equal at both ends ; the avian egg is larger at one end than the other. The most important differences are these : the egg of the bird contains a *chalaza* and *air chamber*, while the egg of the lower Vertebrates does not ; and for the purposes of incubation the bird's egg also contains more albumen, and the shell is much more complex. Impregnation takes place by the spermatozoa of the male being conveyed along the oviducts (or if there are none, directly) to the *cicatricula*.

The coverings which the ovum of the bird obtains in its passage along the oviduct are the following : *Albumen, chalaza, membrana putaminis*, and *calcareous shell*.

The *albumen* is the *white of the egg;* it is secreted by the lining membrane of the oviduct, directly after the ripe ovum has escaped from the ovisac. The ovisac is called in such a case the *calyx* ; the albumen surrounds the *membrana vitelli.*

The *chalaza* is formed by some of this albumen becoming inspissated, and twisted into a small cord at either end of the yelk, during its revolutions.

The *membrana putaminis* is secreted by the oviduct, just before reaching the *uterus* ; it is a thin opaque tough membrane lining the shell; at one end it is separated into two layers, within which is placed some highly oxygenated air, for the chick to respire just before breaking its shell ; this little space is called the *air-chamber.*

The *shell* is secreted by the epithelium of the *uterus* : minute interspaces being left between the calcareous particles for the purpose of transpiration.

CHAPTER XXXVIII.

Organs of Generation, and Mode of Reproduction, amongst Mammalia.

Mammals are all born alive, but the offspring of the two lowest orders, Monotremata and Marsupialia, are so prematurely born as to be termed ovoviviparous, the offspring of all other mammals being viviparous. The male generative organs of mammals present many peculiarities, but all are formed of two dense corpora cavernosa, which are always fixed to the pelvic bones, with a superadded corpus spongiosum ; additional glands to the testes are generally present, none of which are found in the other Vertebrate classes. These are the prostate gland, the vesiculæ seminales, and Cowper's glands ; all of them secrete a fluid which is poured into the urethra, sometimes by separate ducts, sometimes converging to empty themselves into the excretory duct of the testes, called the vas deferens, where they mingle their secretion with the semen.

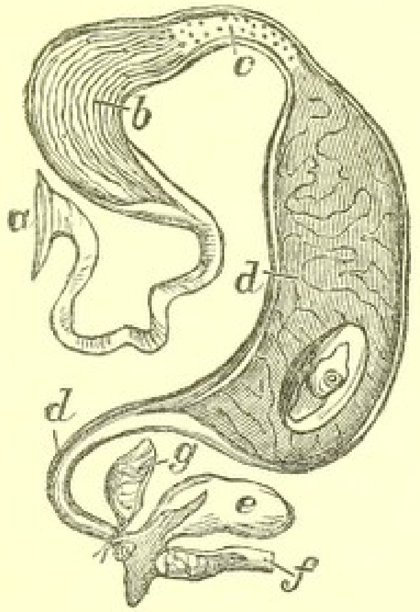
The testes are lodged in the abdomen in the Elephant, the Cetacea, and the Seal ; they pass out of the abdomen through the inguinal canals and rings in most of the other Mammalia, and are lodged in a scrotal bag.

The female organs of generation present even greater varieties than the male. In the Monotremata and Marsupialia the ovaries are large, and, like the ovaries of a bird, racemose or grape-like in their appearance ; the contained ova are correspondingly large, and furnished with a considerable quantity of yelk, which serves as nourishment for the embryo prior to its extrusion from the body of the female. The oviducts, which succeed to the ovaries, present dilatations in part of their course, which dilatations are termed *uteri* ; and these open into a cloacal chamber : not only is there a double uterus in these orders, but the vagina likewise is completely separated into two channels. Prior to birth the embryo derives its nourishment from the surrounding yelk ; the prematurely born offspring is at once transferred by the mother to one of the nipples of the mammary glands, to which it adheres, and where its further development takes place.

In all Mammalia the passages from the ovaries to the uteri are no longer called oviducts, but *Fallopian tubes.* The ovisac is termed the *Graafian vesicle*; this is much denser than the delicate ovisac of the oviparous Vertebrates, and leaves a more or less permanent scar whenever an ovum escapes; this scar constitutes what is known as a *corpus luteum.*

The young of all mammals, except those of Monotremata and Marsupialia, is retained within the uterus until a considerable degree of development has been attained, and as the yelk surrounding the blastoderm becomes more and more scanty, some

Fig. 57.



OVIDUCT OF EMYS, one of Chelonia, to illustrate the situations in which the Ovum obtains its various coverings.

a. Dilated commencement of oviduct, or infundibulum. *b.* Expanded portion with the mucous membrane longitudinally rugous. *c.* Contracted portion, or isthmus. *d.* Larger dilatation, or uterus. *e.* Allantoic bladder. *f.* Cloaca. *g.* Rectum. As to the covering of the egg, the albumen is secreted at *b*, the membrane putaminis at *c*, and the calcareous shell at *d*.

fresh means of support is required for the embryo. A vascular connection is therefore established between the mother and the fœtus, by means of which the latter is supported during the period of gestation; this vascular connection becomes developed into a body called the *placenta.* The Rodents possess a double uterus, like the Marsupials, but the ovaries are no longer racemose, and the Fallopian tubes are very small, showing that the ovum which they conduct to the uterus must likewise be exceedingly minute. In other mammals, the double uteri unite to form a central portion, which is called the *body* of the uterus, and this constitutes the entirety of the organ in the higher mammals. In those mammals which give birth to more than one offspring at a time, we find the sides or *cornua* of the uterus numerous and largely developed; this is especially the case in the Sow. As soon as the ovum is passed from the ovaries along the Fallopian tubes into the uterus, the latter cavity in most Mammalia secretes a thick membrane, which is termed the *decidua*, because it is shed on the expulsion of the fœtus from the uterus.

The shape of the placenta differs widely in the different mammalian orders, and forms an important means of classification; thus it is *zonary* in Carnivora, Proboscidia, and Hyracoidea; it is *discoidal* in Woman, Quadrumana, Insectivora, Cheiroptera, and Rodentia; whilst in Ungulata and Cetacea there is no decidua, hence the placenta is said to be *non-deciduate.*

CHAPTER XXXIX.

Development of Vertebrates.

Up to a certain period the young of all Vertebrates are developed in the same manner. 'No sooner has incubation commenced than the blastoderm becomes distinctly separate from the yelk and the membrana vitelli, and as it begins to spread assumes the form of a central pellucid spot, surrounded by a broad dark ring; it at the same time becomes thickened and prominent, and is soon separable into three layers; of these the exterior is a serous layer; the internal, or that next the yelk, a mucous layer; and between the two is situated a vascular layer, in which vessels soon become apparent. These three layers are of the utmost importance, as from the first-mentioned all the serous structures, from the second all the mucous structures, and from the third the entire vascular system of the embryo originate.

'Towards the close of the first day of incubation the blastoderm has already begun to change its appearance, and two white filaments are apparent in the middle of the central pellucid circle. Supposing a longitudinal section of it at this period, the membrana vitelli will be found to have become more prominent where it passes over the germinal space. At the commencement of the second day the anterior portion of the embryo is dilated, and bent down, so as to inflect the three membranes of the blastoderm at that point. At the conclusion of the second day this inflection is carried still further, and from the vascular layer a single pulsating cavity, the *punctum saliens* (the first appearance of a heart) has become developed. The serous membrane has at the third day become reflected to a considerable distance over the back of the fœtus; at one extremity investing the head with a serous covering, while at the opposite it in like manner covers the tail; it is this reflection of the serous layer which forms the *amnion*. The mucous layer is now seen to line the as yet open space which is to form the abdominal cavity, and by its inflections gives birth to the rudiments of the abdominal viscera. From the vascular layer has been developed the heart. The allantois likewise begins to make its appearance.

. . . About the one hundred and twentieth hour from the commencement of incubation, the vascular layer of the blastoderm has spread extensively over the yelk ; and as the vessels formed by it become perfected, they are found to converge to the navel of the embryo, and to constitute a distinct set of arteries and veins (omphalo-mesenteric), communicating with the aorta and with the heart of the fœtus, and forming a vascular circle surrounding the yelk.

'As soon as the intestinal system of the embryo is distinctly formed, the membrane enclosing the yelk (vitellicle) is seen to communicate with the intestine by a wide duct (ductus vitello-intestinalis), whereby the nutritive substance of the yelk enters the alimentary canal to serve as food. Gradually, as growth advances, the yelk diminishes in size, and at length, before the young bird is hatched, the remains of it are entirely withdrawn into the abdominal cavity, where its absorption is completed.

'While the above phenomena are in progress, the sides of the abdominal cavity, which are still open anteriorly, are occupied by transitory secreting organs, named *corpora Wolffiana.*

'These organs act as temporary kidneys, and pour their secretion into a membranous sac called the allantois. This serves not only as a receptacle for this secretion, but also as a respiratory organ, and is richly supplied with blood. The arteries are derived from the common iliac trunks of the embryo, and of course represent the umbilical arteries of the human fœtus ; the vein enters the umbilicus, and, passing through the fissure of the liver, pours the blood, which it returns from the allantois in an arterialised condition, into the inferior cava, as does the umbilical vein of Mammalia.'[1]

Such are the briefest outlines of the development of the oviparous Vertebrata : let us turn to the viviparous Vertebrata. 'There is not the least doubt that the materials for the earliest growth of the Mammalian embryo are absorbed in the cavity of the womb, and that its formation from a *blastoderm* is exactly comparable to what occurs in the egg of a bird. But precisely at that point of development when the marsupial embryo is expelled from the uterus of its parent, namely, when the functions both of the vitellicle and of the allantoid apparatus become no longer efficient either for nutrition or respiration, a third system of organs is developed in the placental mammifer, whereby a vascular intercommunication is established between the fœtus and the uterine vessels of the mother, forming what

[1] Rymer Jones, *General Structure of the Animal Kingdom.*

has been named by human embryologists the *placenta.*' The vessels which passed merely to the allantois in the bird, now pass from the allantois to the shaggy chorion, where the placenta is becoming developed; and, as this organ grows, the allantoid sac atrophies and disappears. The vitellicle, with its pedicle, are likewise of very small size. The arteries which are diverted from the allantois to the placenta constitute the umbilical arteries; the vein carrying arterial blood, and immensely enlarged, forms the umbilical vein.

CHAPTER XL.

Summary of the Comparative Physiology of Vertebrata.

Prehension, Deglutition, and Digestion.—*Organs of Prehension.* In **Pisces** the jaws, both of which are freely movable, and the teeth, are the sole organs of prehension. The teeth are formed of dentine alone, and are frequently renewed during the life of the fish : they are never lodged in sockets, but are either anchylosed to the bones of the head or connected to them by ligaments. The shape of fishes' teeth is very various, being flat and mosaic-like in some rays, wedge-shaped in the Parrot-fish, finely serrated and lancet-shaped in some of the Selachia ; often conical, or blunt, or pointed.

In **Amphibia** the organs of prehension in Frogs, Toads, and Salamanders are the teeth, assisted by a long and vibratile tongue. In the Siren, or Proteus, the lips are the only prehensile organs.

In **Reptilia** the organs of prehension are various. The Lacertilia employ their jaws and teeth, and often, as in the Chameleon, their tongue. Chelonia use their horny jaws, which are assisted by the long recurved processes in the œsophagus ; Ophidia employ their constricting folds and recurved fangs to capture their prey ; and Crocodilia use their powerful jaws and teeth. The teeth of Reptilia are composed of dentine, crusta petrosa, and, as a rule, enamel. They are generally renewed indefinitely.

In **Aves** the only organ of prehension is the beak, occasionally assisted by the claws in Raptorial birds.

In **Mammalia** various parts are employed as organs of prehension. The Monotremata employ their bill-like mouths ; the Marsupials, Rodents, Quadrumana, and Bimana their fore paws, or hands; some Cetacea, their teeth ; others, a great sieve of whalebone ; some Monkeys, their tails, and many Mammals their teeth alone. The trunk of the Elephant and the snout of the Tapir, too, are prehensile organs. The teeth generally consist of dentine, crusta petrosa, and enamel ; and the first or milk set is, in many Mammals, succeeded by a second or permanent set. There are, however, never more than two sets. They are lodged in sockets, and never occupy any bones but the maxillæ, premaxillæ, and mandible.

Salivary Glands.—**Pisces** do not possess any. **Amphibia** possess buccal salivary glands; and in the Toad and Frog the long tongue is furnished with glands of this character at its base. **Reptilia** all possess them. The poison-glands of Serpents are modified salivary glands. In the Chelonia and Crocodilia the salivary glands are placed behind the lips. In *Aves* they are present, but small, except in the Woodpecker, in which bird they attain a very great size.

Aves.—Some birds possess not only sublingual and submaxillary, but parotid glands, which pour out a copious viscid secretion, which is used as a cement in building their nests. In such cases the nests are edible, *e.g.* those of the Java Swallow.

In **Mammalia,** the aquatic forms, as a rule, such as the Cetacea, do not possess them; but, with these exceptions, they are always present. The Great Ant-eater, *Myrmecophaga jubata*, possesses the largest salivary glands of all Mammalia, the secretion being poured into a salivary bladder situated beneath the mandible. In the Ruminants additional glands, called *glandulæ Harderi*, are present, as well as submaxillary, sublingual, and parotid glands.

Organs of Deglutition.—A pharynx is present in all Vertebrata, whereas no Invertebrate animal possesses one. In **Pisces** the pharynx is short, supported by branchial arches, and leads to the short and wide œsophagus. There is no communication with the nares, which are closed sacs. The pharynx often contains teeth. *Amphibia*, *Reptilia*, and *Aves* all possess simple pharynges, which communicate with the nasal fossæ, and also with the tympanum. The pharynx forms a pseudo-crop in some **Amphibia,** as *e.g.* the Frog, in whom it is a muscular bag appended to the hyoid bone; in the Ophidia it is expansible to an enormous extent; in Chelonia it is large, and studded with long fleshy papillæ. In **Aves** a crop, sometimes double, is present at the upper part of the œsophagus. In **Mammalia,** tonsils are always present, and a soft palate; the uvula is only found in Quadrumana and Man.

Stomach and intestinal canal. **Pisces.**—Stomach generally short and wide, often very indistinctly marked off from the œsophagus; the cardiac orifice is large, and permits of the food being regurgitated for a second mastication by the pharyngeal teeth. Sometimes, as in the Turbot and Carp and most Plagiostomi, the stomach is bent upon itself, or is 'siphonal.'

Again, in some Sharks it is flask-shaped, *e.g.* in the Cornish Porbeagle Shark the cardiac end is as big as a child's head, while the pyloric end only admits a crowquill; in the Teleostei it is more or less tubular. Intestine short and wide; no ileo-cæcal valve; long finger-like processes, the *appendices epiploicæ*, are attached to the small intestine, numerous in the Salmon family, few in number in the Lamprey and Dermopteri generally. In the Shark family a spiral intestinal fold is present in the interior of the gut. Mesentery rarely present. The little Amphioxus possesses cilia in interior of the intestine. The anus is generally placed near the ventral fin.

Amphibia.—Stomach tubular, with the larger opening at the cardiac end. Intestine short in the insectivorous Amphibia, long and convoluted in the vegetable-feeders; no ileo-cæcal valve.

Reptilia.—Stomach in Crocodilia quite of the Avian type, being a strong muscular gizzard, the fibres radiating from two opposite central tendons. In other Reptilia the stomach is tubular, the cardiac being the larger end. A pyloric valve is present. The intestinal canal is for the most part short, but in Ophidia and many Crocodilia, particularly the extinct forms, the absorbing surface is much increased by reduplication of the mucous membrane, something like the spiral fold in the Shark's intestine. An ileo-colic valve is present in Crocodilia and Chelonia, and a cæcum is often present in Chelonia.

Aves.—Stomach, of two distinct sacs, separated by a sphincter muscle at the cardiac end. The upper smaller sac is the *proventriculus*, or true digestive stomach; the lower is the *gizzard* (or *ventriculus bulbosus*), which in the grain-feeders is an immensely strong muscular sac, serving the purpose of a second masticatory apparatus, but in carnivorous birds is a comparatively thin and mammalian-like viscus. Four muscles are found in the gizzard; two large lateral muscles, the *musculi laterales*, and two smaller terminal muscles, the *musculi intermedii*. A pyloric valve is present; in the Ostrich it consists of a series of valvular projecting folds, six or seven deep. The intestinal canal is divided into small and great by the interposition of a double cæcum—the cæca being large, with a long and much convoluted intestine, perhaps eight times the length of the bird in grain-feeders, and being small and the intestine not more than twice the length of the entire body in the birds of prey. No ileo-cæcal valve is present. The intestine ends, as in Reptilia, in a cloaca common to it and to the urino-generative tract. The cul-de-sac of the vitelline duct is persistent, and opens into the upper part of the small intestine.

Mammalia.—Stomach of three kinds; simple, compound, and complex. The simple stomach is a bent sac, lined with a rose-coloured rugous epithelium, and found in Man, Quadrumana, Carnivora, Cheiroptera, and some of the Bruta and Marsupialia. The compound stomach is a sac, more or less divided into partitions by internal septa, or it may possess tubular diverticula connected with it; such a stomach is possessed by Perissodactyla, the herbivorous Cetacea, and Rodentia. The complex *stomach* consists of four distinct sacs or stomachs, called respectively the *paunch* or *ingluvies*, the *water-bag* or *reticulum*, the *manyplies* or *omasum*, and the *rennet* or *abomasum*; it has been sufficiently described in the preceding chapter. Intestine divided into large and small by ileo-cæcal valve, except in Cetacea and some Cheiroptera and Bruta. Small intestine convoluted; large intestine sacculated—the sacculi being produced by the longitudinal muscular fibres being shorter than the gut itself. In some vegetable-feeders, as *e.g.* the Sheep, the intestinal canal is thirty times as long as the entire body; in Carnivorous mammals, on the other hand, it is much shorter, *e.g.* in the Cat, it is only five times as long. It is interesting to note that the *appendix cæci vermiformis* of Man is only found in a few Quadrumana, and in the Wombat, which is a Marsupial animal. This circumstance is very interesting, because the doctrine of evolution must teach us to regard this structure as a relic of the double cæcum found in birds; if this be so, it is singular that the lowest and the highest orders still possess it, while it has quite disappeared in the intermediate species.

Digestive glands in connection with the alimentary canal.—Villi, follicles of Lieberkühn, glandulæ agminatæ, glandulæ solitariæ, and glands of Brünner are present in the intestinal tubes of all the Vertebrata.

Liver.—A liver is also universally present, together with a hepatic portal venous system and a system of capillaries. **Pisces.**—The liver is very large in fish, elongated in long fish, and broad in flat fish. It is often deeply lobed. In **Amphibia** it is two-lobed and large. In **Reptilia** it is large, reaching to the pericardium, and generally two-lobed; but in Ophidia it is undivided. **Aves.**—Liver large and generally bi-lobed, with the apex of the heart between the lobes; central in position to balance the bird. **Mammalia.**—Three-lobed in Ruminants; three- to five-lobed in Carnivora; five-lobed in Quadrumana and Man. Some Mammals possess secondary lobules, generally situated in the right side.

GALL-BLADDER, PANCREAS, AND LACTEAL SYSTEM. **Pisces.**

Analogues of pancreas are the *pyloric cæca*, each, as a rule, communicating with the intestine by a separate opening, but where they are very numerous some of them unite ; in the Plagiostomi, however, although the cæca are numerous, there is only a single aperture into the duodenum. Some Ganoidei possess besides their pyloric cæca a true pancreas. The gall-bladder is present, and connected with the right side of the liver. Lacteals present, but no lymphatic glands.

Amphibia.—Pancreas well formed and provided with a single duct. A gall-bladder is present. Lacteals and lymphatics are present, but no glands. Four so-called 'lymph hearts' are found in the frog, two situated beneath the scapulæ, and two on the sides of the coccyx ; these pulsate regularly, and pump the lymph directly into the veins.

Reptilia.—Pancreas is rather small ; the spleen is well developed. Gall-bladder always present. Lacteals and lymphatics exist, but no glands have been found as yet.

Aves.—Pancreas is composed of three portions, with two or three ducts. The spleen is small. There are two bile-ducts, but only one gall-bladder. Lacteals, lymphatics, lymphatic and lacteal glands, and lymph hearts are frequently all present.

Mammalia.—Pancreas lies in the hollow of the duodenum, as in Aves and Reptilia, and is provided, as a rule, with two ducts. Gall-bladder absent in most Pachydermata, in many Rodentia, and in some of the Bruta ; double in some Cats ; present, but single, in all the rest. Lacteals, lymphatics, with their respective glands, are always present, but none of the Mammalia possess 'lymph hearts.' The way in which these several organs act exactly corresponds to their mode of action in Man ; in the cold-blooded Vertebrata, however, it is necessary to say that the secretions act at a lower temperature than in their warm-blooded congeners. The gastric juice of fish, *e.g.*, which is extremely active in digesting food at a temperature of 40° or 60°, loses its properties on attaining a temperature of 80°, while the mammalian gastric juice is still active at a temperature of 120°.

ORGANS OF CIRCULATION. **Pisces.**—Heart bilocular, situate beneath the gills. The blood passes first into a large *venous sinus*, placed within the pericardium ; secondly, into an *auricle* ; thirdly, into a *ventricle* ; fourthly, into an *arterial bulb* ; fifthly, into *branchial arteries* ; sixthly, into *branchial capillaries*, when the blood is oxygenated ; seventhly, into *branchial veins*, which converge to form (eighthly) the *aorta*, which runs along the dorsal part of the body and yields its blood to (ninthly) *systemic capillaries*, whence (tenthly) it is re-directed to the venous sinus by a great *caval vein.* The auriculo-ventricular valve is guarded by two semi-lunar valves, in the Teleostei, and by valves with tendinous chords in the Shark family. The *bulbus arteriosus*

Fig. 58.

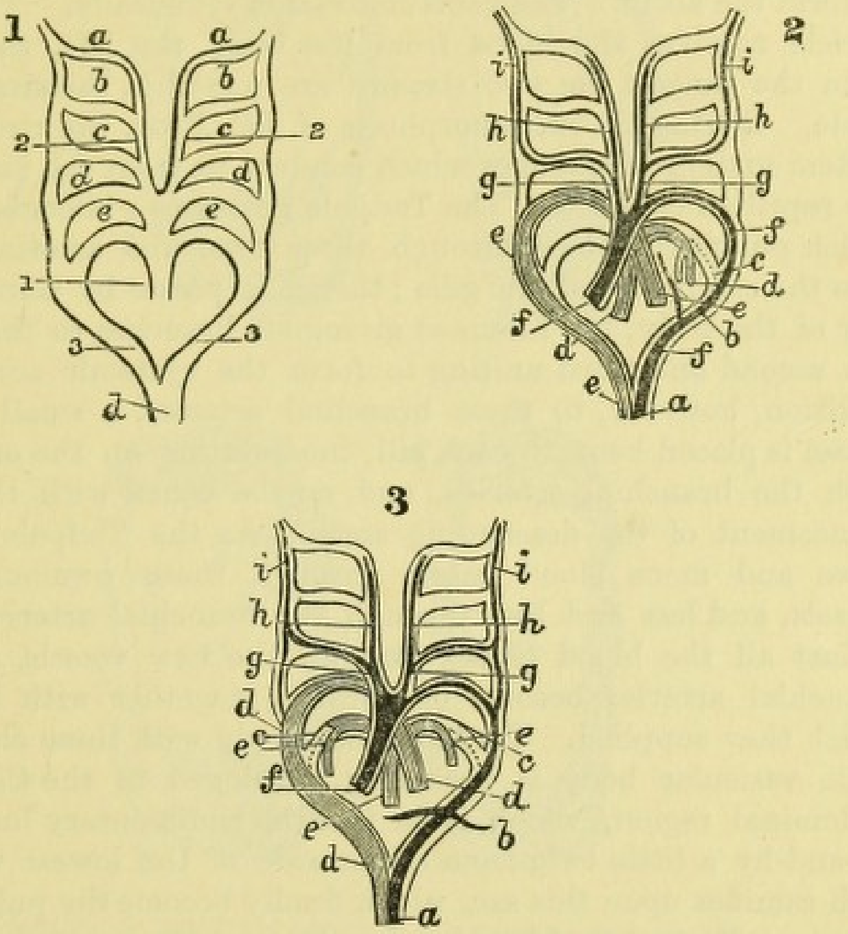


Diagram of the Primitive Aortic Arches of Mammals, Birds, and Reptiles.

1. Common trunk or root of aorta. 2. The two branches into which it divides, and which give off the successive arches, *a*, *b*, *c*, *d*, and *e*, which end in 3, the descending aorta.
2. Vessels and aortic arches of a Snake, and the changes which the primitive condition shown in preceding figure has undergone. In this and the following figure, the parts left blank are those which abort. *a*. Descending aorta. *b*, *c*. Remnant of a primitive aortic arch, *e*, in fig. 1, or ductus Botalli. *d*. Pulmonary artery. *e*, *e*. Left aortic arch. *f*. Right principal aortic arch. *g*. Common carotids. *h*. External carotids. *i*. Internal carotids.
3. Vessels and aortic arches of a Lizard. *a*. Descending aorta. *b*. Subclavian arteries. *c*. Rudiments of 1st (right and left) arches. *d*. Left aortic arch. *e*, *e*. Pulmonary arteries. *f*. Right principal aortic arch. *g*. Common carotids. *h*. External carotids. *i*. Internal carotids.

in the last-named group is provided with several tiers of valves, preventing regurgitation into the ventricle ; in Teleostei there is only a single row. The Amphioxus does not possess a heart ;

but there are several sacs in connection with the blood-vessels which contract rhythmically.

Amphibia. — Heart trilocular, two auricles, and one ventricle ; to which succeeds a *bulbus arteriosus.* This gives off two arteries, which first of all give off the carotids and subclavian arteries, and then, arching round the œsophagus, unite to form the aorta. The veins contract rhythmically. The right auricle receives the blood from the body, the left, the blood from the lungs ; the two streams are mixed in the single ventricle. During the metamorphosis of the Frog, the circulatory system undergoes changes which conduct us from the piscine to the reptilian condition. The Tadpole possesses a bilocular heart, which pumps the blood through three branchial arterial arches into the capillaries of the gills ; thence it passes by veins to the rest of the body, the foremost giving off branches to the head, the second and third uniting to form the systemic aorta. In addition, however, to these branchial arteries, a small arched vessel is placed beneath each gill, inosculating on the one hand with the branchial arteries, and on the other with the commencement of the descending aorta. As the Tadpole grows, more and more blood passes through these communicating vessels, and less and less through the branchial arteries, until at last all the blood passes through the new vessels, and the branchial arteries become obliterated, together with the gills which they supplied. Contemporaneously with these changes a little vesicular body is becoming developed in the thoracico-abdominal region, which is in fact the rudimentary lung, and by-and-by a little twig from either side of the lowest vascular arch ramifies upon this sac, which finally become the pulmonary arteries. Part of the blood leaving the ventricle now enters these pulmonary arteries, the rest enters the two remaining vascular arches, part going to the head, but the greater part entering the aorta. The blood returning from the lungs gradually acquires a separate chamber for itself, and so the left auricle is produced. This constitutes the Reptilian character of circulation; the further changes necessary to establish the perfectly double circulation of Birds and Mammals simply consist in the development of a ventricular septum.

Reptilia.—Heart trilocular in the lower, imperfectly four-chambered by a partial ventricular septum in the Crocodilia. There are always two aortæ, right and left, which, after supplying the head and anterior limbs, unite to form a single vessel. The right or systemic auricle is larger than the left.

Aves.—Heart quadrilocular, the right side containing venous blood, and the left pure arterial blood. The heart, like most

Fig. 59.

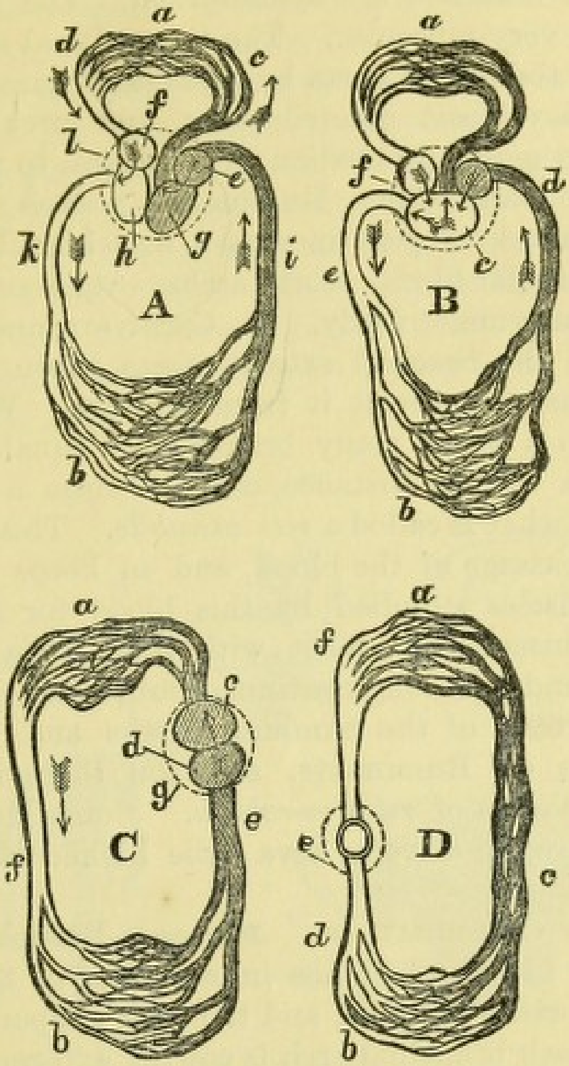


DIAGRAM OF THE CIRCULATION IN VERTEBRATA AND MOLLUSCA.

Birds and Mammals.

Fig. A. *a*. Lesser or pulmonary circulation. *b*. Greater or systemic circulation. *c*. Pulmonary artery. *d*. Pulmonary veins. *e*. Right auricle. *f*. Left auricle. *g*. Right ventricle. *h*. Left ventricle. *i*. Vena cava. *k*. Aorta. *l*. Heart.

Reptiles.

Fig. B. *a* and *b* as above. *c*. Single ventricle. *d*. Vena cava. *e*. Aorta. *f*. Heart.

Fishes.

Fig. C. *a* and *b* as above. *c*. Ventricle. *d*. Auricle. *e*. Veins. *f*. Dorsal artery. *g*. Heart.

Mollusca.

Fig. D. *a* and *b* as above. *c*. Veins. *d*. Arteries. *e*. Heart. *f*. Branchio-cardiac canals.

of the other viscera, is placed quite centrally, so as to balance the bird. The aorta arches over the root of the right lung, and all its arterial branches are symmetrical. The heart of birds is conical, and very muscular. The femoral and sciatic arteries arise from the abdominal aorta by separate origins.

Mammalia.—Heart quadrilocular, and circulation always double. Heart generally median, but inclines to the left in the Anthropomorpha and Man. Ruminantia possess a bone at the base of the breast to give increased attachment of origin to ventricular muscular fibres. Aorta arches over root of left lung, and branches unsymmetrically. In Carnivora and other leaping Mammals, the brachial artery passes through a foramen in the humerus, to protect it from pressure. When a vessel breaks up into a great many branches of equal size, which, after passing a certain distance, unite to form a single trunk again, we have what is called a *rete mirabile*. This arrangement facilitates the passage of the blood, and so keeps up the vital tone of the muscles supplied by this blood for a lengthened period ; we consequently meet with these *retia mirabilia* in animals that undergo long-continued muscular exertion ; *e.g.* the axillary artery of the climbing Sloths and Lemurs, the carotid arteries of Ruminants, and the thoracic arteries of Cetacea are instances of *retia mirabilia*. Some Mammalia possess a double superior vena cava ; the higher Mammals only possess a single one.

ORGANS OF RESPIRATION. **Pisces.**—Branchia or gills. There are five branchial arches in each side of the head, the first four supporting the gills, and the fifth supporting pharyngeal teeth. Each branchial arch is convex externally and concave internally ; it supports the branchiæ as the back of a comb supports the teeth. Each of the processes is covered with a rich vascular capillary plexus. The branchial artery, carrying venous blood, runs on one side, and the branchial veins, carrying pure blood, on the other : the capillaries are between the two. The water, containing the oxygen, is taken in through the mouth, passed over the gills, and then expelled through a large slit, which is guarded by a membranous fold supported by the branchiostegal rays. The gill cover is the operculum.

Besides the gills, many fish possess an air-bladder, which is the rudimentary homologue of the lungs. It is placed dorsally and variously shaped, being fringed in the Cod, single in the Perch, constricted in the Carp tribe, furnished with large processes in the Gurnard, &c.

In most Fishes, a duct, called the 'pneumatic duct,' connects the air-bladder with the pharynx or œsophagus. When this is not the case, the sac is filled with gas by a process of secretion from the blood. Its interior is vascular, and contains gas, chiefly nitrogen, and a little oxygen. It is mainly hydrostatic in function. Fishes are suffocated when removed from the water, because the gills become clogged, and so arrest the circulation and respiration.

Amphibia.—All Amphibia, when young, possess *external* gills. They project from the sides of the head into the water, and are slightly and minutely branched. The lowest Amphibia, such as the Siren, Proteus, and Axolotl, retain these external gills throughout the whole of life ; higher forms, such as the Triton, retain them for a few days after birth ; and the highest, such as Frogs, only possess them for a very short time after extrusion from the egg.

Fig. 60.

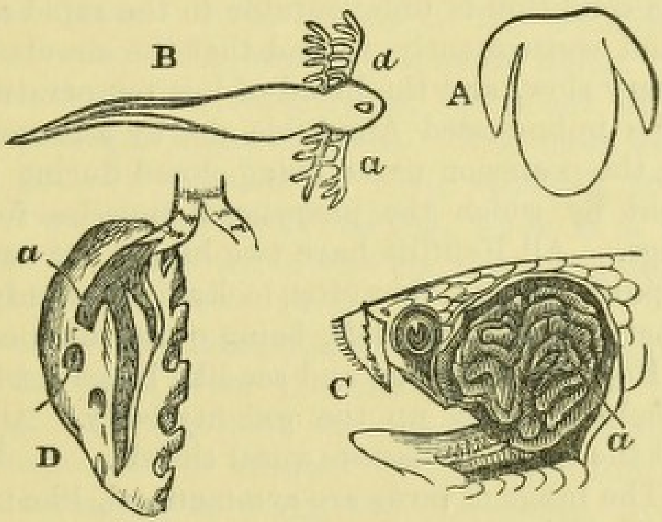


DIAGRAM ILLUSTRATIVE OF THE RESPIRATORY ORGANS OF VERTEBRATA.

A. Swim bladder of Gurnard. B. External gills of Tadpole. C. Gills of a fish (*Anabas*). D. Lungs of a bird, showing at *a* the bronchial tube passing through the lung and opening freely into the thoracico-abdominal cavity.

Besides these external gills, some Amphibia possess *internal* gills. They are, as a rule, transitional organs, as *e.g.* in the Frog, when they grow, decline, and fall during the development of the lungs. The internal gills are attached to the hyoid apparatus ; they are lodged in a branchial chamber, and water is admitted to them through the nose or mouth, the same water being discharged through a slit on the left side of the neck. The Caducibranchiate Amphibia respire in their adult condition by lungs. These are two sac-like organs, which communicate with a larynx and the mouth ; the larynx, in fact, makes its first appearance in the Amphibia, and the croaking of the Frog may be regarded as the first specimen of true vocal music in any animal. Inspiration is performed in a manner somewhat peculiar to the class : there are muscles of inspiration resembling those of Mammals. The throat muscles attached to the hyoid bone are strong ; air is swallowed into the pharynx, and then, the nostrils being closed by valvular flaps, is pumped through the glottis into the lungs by contraction of the pharyngeal muscles : there is no epiglottis to prevent the air entering the lungs. The structure of the Amphibian lung is subcellular ; the bronchus ends abruptly in this general mass of subcellular lung. The skin acts as an auxiliary respiratory organ, possessing the power of absorbing oxygen and exhaling carbonic acid.

Reptilia.—All breathe by lungs ; these organs, however, are never so finely cellular as in the higher classes of Birds and Mammals, the bronchi ending abruptly in the honeycomb-like mass. This condition is unfavourable to the rapid aëration of the blood, and consequently we find that the circulation of the Reptilia is very slow, and the blood of low temperature. They inhale, as the pulmonated Amphibia do, by a process akin to deglutition ; the posterior nares being closed during the pumping movement by which the pharyngeal muscles force the air into the lungs. All Reptilia have two lungs, but owing to the peculiar shape of Ophidia, they often look as if they only possessed one, the other, which is the left, being quite rudimentary. In the aquatic Reptilia, the large and sac-like lungs act hydrostatically, and help to buoy up the weighty body. A trachea is present, and the larynx possesses vocal chords.

Aves.—The lungs of birds are symmetrical, like most of the other organs ; they are also very finely cellular, in accordance with the high degree of perfection to which the respiratory function is carried in these animals, and also *en rapport* with the high temperature of the blood.

In the larger Birds the bronchial tubes divide dichotomously upwards of seventy times before terminating in the avian air-cells. Expiration is an active muscular movement, while inspiration follows as a passive result of the muscular tension being taken off ; when a bird expires, the large sternum, carrying with it the ribs, is bent towards the spine, and when this action ceases, the bent ribs (for they will bend considerably) resume their normal position by an inherent function of resiliency or elasticity. The air does not, however, remain in the lungs only of birds, but passes through large openings into the common thoracico-abdominal cavity, and also into the hollow pneumatic bones : all these arrangements being designed to lighten the body of the bird. In addition to these osseous cavities, birds possess *air-sacs* appended to different parts of the body, in the neck, body, or limbs, which serve a similar purpose to the loculi in the bones. By these arrangements the respiratory air, in many birds, after traversing the lungs passes into the abdomen, which is not (except in the Apteryx and a few others) separated from the thorax by a diaphragm, and into the upper limbs of birds of flight, into the lower, or hinder, in cursorial birds. The tracheal passages present an upper larynx, a trachea, and a lower larynx. The upper larynx is small, it is not supplied with true vocal chords, but is worked by efficient muscles ; the latter, however, are not numerous, and a sphincter answers the purpose of the greater number of the laryngeal muscles known in Man. The larynx is often long and composed of entire rings of cartilage. The lower larynx, or *syrinx*, is a much larger box than the upper, and somewhat resembles an irregular drum. It is largest in the aquatic birds, it is auxiliary to vocalisation, and is probably useful in forming a reservoir for air during submersion, but is not, as is commonly stated, the principal organ of voice. The most beautiful songsters, who are also notable for their strength of voice, have scarcely a trace of this second larynx, while it is most highly developed in the Duck tribe, who are not remarkable either for the sweetness or the power of their voice.

Mammalia.—The Mammalia all possess a diaphragm (which shuts off the thorax from the abdomen), and a pair of finely cellular lungs ; the right one being, as a rule, the larger. The action of inspiration is effected by muscular contraction ; the chief muscles employed being the diaphragm, external intercostal muscles, pectoralis major, serratus posticus superior, and levatores costarum ; the action of expiration is effected by the resilience of the ribs, costal cartilages, and lungs themselves, aided by muscles, the chief of which are the internal intercostals, the serratus posticus inferior, and the muscles of the abdominal wall. Some mammals, as *e.g.* the Horse, Elephant, and Cetacea, have simple, undivided lungs, but in most mammals they are divided into from three to five lobes.

ORGAN OF VOICE. **Pisces.**—Some Fish, when taken from the water, produce a noise, but this is not a laryngeal note, but caused by the flapping of the gill covers, and the Tambour Fish produces a loudish note when in the water, by the repeated contractions of the muscular walls of its large air-bladder.

Amphibia possess a larynx, and often membranous vocal chords, but no trachea, the larynx ending abruptly in the lungs.

Reptilia possess a larynx and trachea, but are endowed with very limited vocal powers. The hissing of snakes is caused by the air being forcibly expelled through the glottis, there being no vocal chords.

Aves, as before stated, possess an upper and a lower larynx connected by a trachea. The upper larynx is supplied with a sphincter muscle, but does not possess vocal chords. The lower larynx is placed at the lower end of the trachea, just before it bifurcates into the two bronchi. It is, except in the Parrot, nearly always a double and symmetrical organ. A bone called the os transversale is thrown across the upper opening of the two bronchi, having a membrane connected with its upper and its lower border ; the upper membrane is called the *membrana semilunaria*, and the lower is the *membrana tympaniformis*. Both the upper, or larynx proper, and the lower, or syrinx, are probably concerned in vocalisation ; inasmuch, however, as the lower organ is very ill-developed in songsters, and most highly developed in aquatic Birds, it is probably subservient, as before stated, to other functions than those of voice.

Mammalia.—In most the organ of voice is fashioned much as in man, but some few Mammals are voiceless, viz. the Giraffe, Armadillo, Porcupine, and all the Cetacea—the bellowing of the latter animals being produced by the forcible expulsion of the water from the spiracles. Many Mammals possess large air-sacs in connection with the larynx, which act as sounding boards, and increase the reverberation of the voice; the bray of the Ass and the howl of the Mycetes Monkey are due to these organs. If air be forcibly passed, by a bellows, for example, through the trachea of any animal, when the windpipe is removed from the body, a note is produced similar to the natural cry of the animal. Both in Mammals and birds the voice is pitched in the minor key.

NERVOUS SYSTEM. **Pisces.** *Spinal cord* is uniform in diameter, and smaller than in other Vertebrates, in accordance with the limited variety of movements performed by the fish. *Medulla oblongata* sometimes divided into two perfectly distinct halves, and generally very simple in construction, but it possesses a *nodule* on the floor of the fourth ventricle, and two lobes (vagal) in connection with the vagus nerve.

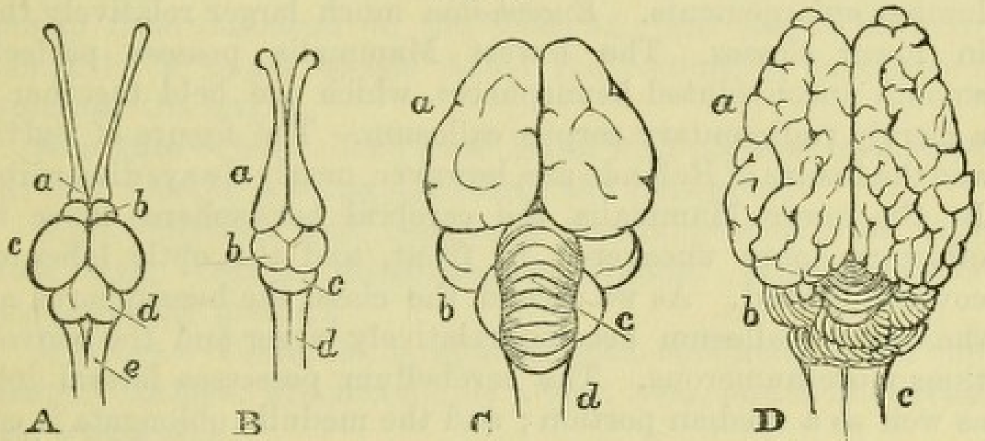
Encephalon consists of three pairs of symmetrical ganglia, which are from before backwards, olfactory lobes, corpora striata, and optic lobes. The lower part of the optic lobes encloses the third ventricle, the upper part is connected with the pineal gland above, and the pituitary body below.

The corpora striata, homologues of the cerebral hemispheres, are often smaller than the optic lobes. In some fish (Plagiostomi) the cerebral hemispheres contain a small cavity or lateral ventricle. The olfactory lobes are elongated, and sometimes placed considerably in advance of the rest of the encephalon.

Cerebellum is comparatively large; it is a single median lobe, which answers to the vermiform process in Man. There is no pons Varolii.

Amphibia.—In the Perennibranchiata the *spinal cord* is small and uniform in size; in the Caducibranchiata it is larger, with two distinct enlargements corresponding to the origin of the nerves of the fore and hind limbs. *Encephalon.* The olfactory lobes are sessile. The cerebral lobes are relatively

Fig. 61.



BRAINS OF A FISH, AN AMPHIBIAN, A BIRD, AND A MAMMAL.

A. Herring. *a*, Rhinencephalon or olfactory lobes. *b*. Prosencephalon or corpora striata, the only representatives of the cerebral hemispheres. *c*. Mesencephalon or optic lobes. *d*. Metencephalon or cerebellum. *e*. Medulla oblongata. B. Frog. *a*. Olfactory lobes. *b*. Optic lobes. *c*. Cerebellum. *d*. Medulla oblongata. C. Fowl. *a*. Cerebral hemispheres, which here quite conceal the olfactory lobes in front, but leave the optic lobes, *b*. exposed laterally and inferiorly behind. *c*. Cerebellum. *d*. Medulla oblongata. D. Sheep. *a*. Cerebral hemispheres. *b*. Cerebellum. *c*. Medulla oblongata.

larger than in fish; the optic lobes are still bigeminal, and the cerebellum single, median, and very small. There is no pons Varolii.

Reptilia.—In Ophidia the *spinal cord* is uniform, but it presents two ganglionic enlargements in all other Reptilia. *Encephalon.* The olfactory lobes are small. The cerebral lobes have now attained a considerable size; they are hollow, and the corpora striata and thalami optici can be distinctly made out The optic lobes now present the form of corpora quadrigemina and are quite insignificant in proportion to the cerebral lobes. The cerebellum is still median in position, and consists of a single lobe. There is no pons Varolii. The cerebral lobes present a fissure, which is the homologue of the fissure of Sylvius.

Aves.—*Spinal cord* tapers to the lower end, and presents two distinct enlargements, corresponding to the pectoral and pelvic limbs. *Encephalon.* The olfactory lobes are hidden by the cerebral lobes, which have now attained the condition of cerebral hemispheres. The latter are hollow; they possess corpora striata, thalami optici, a round commissure, and a rudimentary fornix. There is, however, no corpus callosum, nor are there any cerebral convolutions. The optic lobes are placed below and on either side of the cerebral hemispheres. The cerebellum still only consists of the median lobe, but is marked by transverse striæ.

Mammalia.—*Spinal cord* always presents cervical and lumbar enlargements. *Encephalon* much larger relatively than in lower classes. The lowest Mammalia possess perfectly smooth unconvoluted hemispheres, which are held together by a merely rudimentary corpus callosum. The fissure of Sylvius and the fissure of Rolando are, however, nearly always discernible. In the lower Mammalia the cerebral hemispheres leave the olfactory lobes uncovered in front, and the optic lobes uncovered behind. As we ascend the class, the hemispheres and the corpus callosum become relatively larger and the convolutions more numerous. The cerebellum possesses lateral lobes as well as a median portion; and the medulla oblongata is connected by a well-marked decussation of the anterior pyramids.

The relative weights of the encephalon, as compared with the body, are in Fishes 1 to 5,668; in Reptilia, 1 to 1,321; in Aves, 1 to 212; and in Mammalia, 1 to 186. Amongst the latter, many variations occur, *e.g.*, in the Horse it is as 1 to 400; in the Dog, 1 to 305; in the Cat, 1 to 156; in Man it is about 1 to 40. Some animals possess a relatively heavier brain than Man, *e.g.* in the Marmoset Monkey it is 1 to 22, and in the Tit 1 to 12; in the Anthropomorpha it is 1 to 50. No animal, however, has a brain which can be compared to that of Man for the extent or number of the convolutions, and corresponding quantity of grey matter; whilst the angular convolution, the hippocampus minor, and the marked asymmetry of the two hemispheres, are features possessed by the brain of Man alone. The brain of Man weighs about 58 oz., that of the Whalebone Whale about 5 lbs., and that of the Elephant about 10 lbs.; the latter has therefore the heaviest brain in the entire Animal Kingdom.

ORGANS OF SENSE. **Pisces.** *Smell.*—Nasal fossæ are culs-de-sac, lined by ciliated epithelium, sometimes plicated.

Sight.—No eyelids or lachrymal gland. Cornea flat. Sclerotic very thick behind. Choroid and iris not remarkable.

Retina plicated like a lady's fan. An additional structure, called the 'choroid gland,' is placed around the entrance of the optic nerve, between the layers of the choroid.

Hearing.—A vestibule is present, containing otoliths and a fluid, communicating with the auditory nerve, but not externally. Semicircular canals sometimes added.

Amphibia.—*Smell.* Nasal fossæ communicate with mouth, lined by smooth ciliated epithelium.

Sight.—Eyelids and lachrymal glands present. The eyes are large, and a third hyelid or nictitating membrane is often present.

Hearing.—Vestibule, and tympanum with Eustachian tubes passing from the latter to the pharynx : the tympanum is traversed by a single ossicle called the columella, supposed to represent the stapes.

Reptilia.—*Smell.* Two nasal fossæ with plicated membrane, but only a single opening anteriorly and posteriorly.

Sight.—Eyelids and lachrymal glands present ; the latter often large. Ophidia do not possess eyelids. Membrana nictitans generally present.

Hearing.—Vestibule, tympanum with columella, and a rudimentary cochlea, which is simply a bent tube, and is not divided into true scalæ.

Aves.—*Smell.* Nasal fossæ distinct, but mucous membrane only slightly plicated : no cartilages are present.

Sight.—Eyelids with membrana nictitans, and lachrymal glands. Sclerotic strengthened with osseous plates. Iris contains striated muscular fibres.

An additional structure, called the 'pecten,' or marsupium, is found in the vitreous humour, extended between the optic nerve and the lens.

Hearing.—Sometimes external meatus, but never pinna. Tympanum with single ossicle, the columella. Vestibule and cochlea, the latter more spiral than in Reptilia.

Mammalia.—*Smell.* Nasal fossæ always distinct. Mucous membrane often much plicated, and turbinals much convoluted.

Sight.—Nothing remarkable.

Hearing.—Pinna (except in Cetacea and Seals), external meatus, tympanum with three ossicles, *malleus, stapes,* and *incus* ; vestibule, three semicircular canals, and a cochlea forming two and a half turns, and divided by a median partition into two scalæ ; the *scala tympani* communicating with the tympanum, and the *scala vestibuli* communicating with the vestibule.

Excretory Organs.— **Pisces.** The kidneys are chiefly supplied with venous blood: they are large, generally placed above the air-bladder, and attached to the vertebral colum. The cortical substance is alone present, *i.e.* the convoluted tubes end at once in the ureters. They represent the temporary kidneys of the higher Vertebrata, or the Wolffian bodies. The uriniferous tubes of fishes are ciliated.

Amphibia.—The renal arteries, as in Pisces, are numerous, and the kidneys also receive much venous blood. The kidneys themselves are elongated, with a narrow anterior extremity. They are dorsal in position, and pour their secretion through a narrow ureter into a common cloaca.

Reptilia.—Renal arteries still numerous, and much venous blood goes to the organs. Kidneys dorsal in position, generally large. Cortical substance alone represented. Ureters long, narrow, and end in a cloaca. In Ophidia they are asymmetrical, like most of the other organs, the right being higher than the left. The secretion in these animals is almost solid, consisting nearly entirely of uric acid, the solidity being due to the small quantity of fluid drunk by serpents.

Aves.—Renal arteries numerous, and venous blood abundant, from which source indeed the urine in all the preceding classes is secreted. Kidneys are large, and lodged beneath the vertebral column, following the inequalities of this region. Cortical substance alone represented. The ureters end in a cloaca, in which, however, there is a recess, which is sometimes regarded as a rudimentary bladder.

Mammalia.—Renal arteries, two in number, which alone nourish the kidneys, no venous blood directly supplying these organs. Both cortical and medullary portions present in adult condition. In the embryological state the kidneys are always much lobulated, and this lobular condition is persistent in many mammals, *e.g.* in Bears, Ruminants, Otters, Seals, and the Cetacea.

Organs of Reproduction.—A separate description of these organs is given in Chapters XXXVII. and XXXVIII.

GLOSSARY.

Abomasum, the fourth compartment of the compound stomach of Ruminantia.

Abranchiate (ἀ, without; βράγχια, gills), devoid of gills.

Acalephæ (ἀκαλήφη, a nettle), an order of Hydrozoa, named from the property they possess of stinging.

Acanthocephala (ἄκανθα, a thorn; κεφαλή, head), parasitic worms grouped under Scolecida.

Acarina (ἄκαρι, a mite), an order of Arachnida.

Acephalous (ἀ, without; κεφαλή, the head), destitute of a distinct head.

Acetabulum, the socket of the hip-joint in Vertebrata.

Acrita (ἄκριτος), confused. Synonym of Protozoa.

Actinosoma (ἀκτίς, a ray; σῶμα, body), a term used to signify the entire body of an Actinozoon, whether simple or compound.

Actinozoa (ἀκτίς, a ray; ζῶον, an animal), a class of Cœlenterata.

Adelthrosomata (ἄδηλος, hidden; ἄρθρον, a joint; σῶμα, body), an order of Arachnida.

Agamic (ἀ, without; γάμος, marriage), term employed in a sexual reproduction.

Allantois (ἀλλᾶς, a sausage), one of the fœtal membranes present in some of the Vertebrata.

Ambulacra (ambulacrum, a garden walk), the perforated spaces in the shell of Echinus.

Ametabolic (ἀ, without; μεταβολή, change), applied to insects that do not pass through a metamorphosis during growth.

Amnion (ἀμνός, a lamb), one of the fœtal membranes of certain Vertebrata.

Amœba (ἀμοιβός, changing), an order of Rhizopoda.

Amphibia (ἀμφί, both; βίος, life), applied to such animals as frogs, which live both on land and in water.

Amphicœlous (ἀμφί, both; κοῖλος, hollow), vertebræ with a cup at either end.

Amphioxus (ἀμφί both; ὀξύς, sharp), the Lancelet, which tapers to either end of its body.

Amphipoda (ἀμφί, both; πούς, foot), an order of Crustacea, whose feet serve both for walking and swimming.

Anarthropoda (ἀ, without; ἄρθρον, a joint), Annulosa which do not possess jointed appendages.

Anchylosis (ἄγχυλος, crooked), the union of the two surfaces of a joint by bone, so that all movement is lost.

Annuloida (*annelus*, dim. of *annulus*, a ring; εἶδος, form), subkingdom of Echinodermata and Scolecida.

Annulosa (*annulus*, a ring). Subkingdom of jointed animals, including Anarthropoda and Arthropoda.

Anomura (ἄνομος, irregular; οὐρά, a tail), a tribe of Crustacea.

Anoplura (ἄνοπλος, unarmed; οὐρά, a tail), an order of Insecta.

Anoura (ἀ, without; οὐρά, a tail), an order of Amphibia, including frogs and toads.

Antennæ (*antenna*, the yard-arm of a ship), the horns or feelers of Arthropoda.

Anthozoa (ἄνθος, a flower; ζῶον, an animal), a class of Cœlenterata generally termed Actinozoa.

Anthropoid (ἄνθρωπος, a man; εἶδος, like). The highest order of apes.

Antlia (ἀντλίον, or ἀντλία, a pump). The spiral trunk of Lepidoptera.

Aphaniptera (ἀφανής, inconspicuous; πτερόν, a wing), an order of Insecta.

Apoda (ἀ, without; πούς, a foot), fishes which have no ventral fins.

Apodemata (ἀποδαίω, I portion off), the chitonous septa which divide the somites in Crustacea.

Aproctous (ἀ, without; πρωκτός, anus), having no anal aperture.

Aptera (ἀ, without; πτερόν, a wing), the wingless Insecta.

Apteryx (ἀ, without; πτέρυξ, a wing), a New Zealand bird which only possesses the rudiments of wings.

Arachnida (ἀράχνη, a spider), a class of Arthropoda.

Archæopteryx (ἀρχαῖος, ancient; πτέρυξ, a wing), a fossil bird which possessed a tail of true vertebræ.

Arthrogastra (ἀρθρόν, a joint; γάστηρ, the belly), an order of Arachnida.

Artiodactyla (ἄρτιος, even; δάκτυλος, a finger), the cloven-footed quadrupeds.

Ascidioida (ἀσκός, a bag), or Tunicata, an order of Molluscoida.

Atrium (*atrium*, a hall), the large cloaca or chamber into which the intestine of Ascidioida opens.

Autophagi (αὐτός, self; φάγειν, to eat), birds whose young are independent of the mother's care on their escape from the egg.

Avicularium (*avicula*, dim. of *avis*, a bird), peculiar little processes found in many of the Polyzoa, shaped like a bird's beak.

Bacterium (βακτήριον, a staff), minute filamentous organisms found in decomposing infusions of organic matter.

Balanidæ (βάλανος, an acorn), the acorn shells, a family of Cirripedia.

Batrachia (βάτραχος, a frog), formerly applied to the whole class of Amphibia, now restricted to frogs and toads, the *Anoura*.

Belemnite (βέλεμνον, a dart), a fossil genus of Cephalopoda.

Blastoidea (βλαστός, a germ; εἶδος, form), an order of Echinodermata, now extinct.

Brachyura (βράχυς, short; οὐρά, a tail), the crabs, a family of decapod Crustaceans.

Bradypodidæ (βραδύς, slow; πούς, a foot), the sloths.

Branchiostegal (βράγχια, the gills; στέγω, I cover), the membrane which covers the gills of fish.

Bruta (*brutus*, heavy), an order of Mammalia, sometimes called Edentata.

Bryozoa (βρύον, moss; ζῶον, an animal), an order of Molluscoida, now called Polyzoa.

Byssus (βύσσος, flax), the thread-like filaments by which mussels and other Mollusca attach themselves to rocks, &c.

Caducibranchiate (*caducus*, falling off; βράγχια, gills).

Calycophoridæ (κάλυξ, a cup; φέρω, I bear), an order of Hydrozoa.

Campanularida (Campanula, a bell), an order of Hydrozoa.

Carinatæ (*carina*, a keel), birds who possess a keeled sternum.

Catarhina (κατά, downwards; ῥίς, ῥινός, the nose), a family of Quadrumana comprising the anthropoid or tailless apes.

Cavicornia (*cavus*, hollow; *cornu*, a horn), Ruminants with hollow horns.

Cephalopoda (κεφαλή, head; πούς, a foot), the highest class of Mollusca, *e.g.* the cuttle fish.

Cestoidea (κέστος, a girdle), now called Tæniada, intestinal worms with flat tape-like bodies.

Cestraphori (κέστρα, a weapon; φέρω, I bear), a family of Elasmobranchii or sharks.

Cetacea (κῆτος, a whale), the order of whales.

Chætognatha (χαίτη, hair; γνάθος, jaw), a class or order of Annulosa containing only Sagitta.

Cheiroptera (χείρ, hand; πτερόν, wing), the bats, an order of Mammalia.

Chelæ (χηλή, a claw), the prehensile claws terminating the limbs of some Crustacea, *e.g.* the lobster.

Chelonia (χελώνη, a tortoise), an order of Reptilia.

Chilognatha (χεῖλος, a lip; γνάθος, a jaw), an order of Myriapoda.

Chilopoda (χεῖλος, a lip; πούς, a foot), an order of Myriapoda.

Chitine (χιτών, a coat), the horny covering which forms the exoskeleton of many Invertebrata, *e.g.* of the beetles.

Ciliograda (*cilium*, an eyelash; *gradior*, I walk), or Ctenophora, an order of Actinozoa.

Cirripedia (*cirrus*, a curl; *pes*, a foot), a group of Crustacea, *e.g.* the barnacles.

Cirrostomi (*cirrus*, a curl; στόμα, mouth), an order of fishes—otherwise called Pharyngobranchii.

Coccoliths (κόκκος, a berry; λίθος, a stone), round bodies found on Coccospheres.

Coccospheres (κόκκος; σφαῖρα, a sphere), larger masses of sarcode often found on low forms of Protozoa.

Cœlenterata (κοῖλος, hollow; ἔντερον, intestine), the sub-kingdom of Invertebrata, comprising Hydrozoa and Actinozoa.

Cœnenchyma (κοινός, common; ἔγχυμα, tissue), the common support of compound corals.

Cœnœcium (κοινός, common; οἶκος, house), sometimes called polyzoary, and signifying the entire dermal system of a Polyzoon.

Cœnosarc (κοινός; σάρξ, flesh), the common stem of Hydrozoa.

Coleoptera (κολεός, a sheath; πτερόν, a wing), the beetles whose anterior wings protect their posterior.

Conirostres (κῶνος, a cone; *rostrum*, a beak), an order of insessorial or perching birds.

Copepoda (κώπη, an oar; πούς, a foot) an order of Crustacea.

Crinoidea (κρίνον, a lily; εἶδος, form), an order of Echinodermata.

Crustacea (*crusta*, a crust), a class of Annulosa, comprising crabs and lobsters.

Ctenocyst (κτείς, a comb; κύστις, a bag), the sense organ of Ctenophora.

Ctenoid (κτείς, a comb; εἶδος, form), fish-scales with fringed edges, *e.g.* those of the Sole.

Ctenophora (κτείς, a comb); φέρω, I bear), an order of Actinozoa.

Cycloid (κύκλος, a circle; εἶδος, form), fish-scales with an even margin, *e.g.*, those of the dace.

Cyclostomi (κύκλος, a circle; στόμα, mouth), an order of fishes, otherwise called Marsipobranchii.

Cystica (κύστις, a sac), the embryonic forms of tapeworms.

Cystoidea (κύστις, a sac; εἶδος, form), an order of Echinodermata, now extinct.

Decollated (*decollo*, I behead), univalve shells, whose apex falls off during growth.

Deinosauria (δεινός, terrible; σαύρα, a lizard), an extinct order of Reptilia.

Dentirostres (*dens*, a tooth; *rostrum*, a beak), perching birds with a toothed mandible.

Dibranchiata (δίς, double; βράγχια, gills), an order of Cephalopoda.

Dicynodontia (δίς, double; κύων, a dog; ὀδούς, a tooth), an extinct order of Reptilia.

Didelphia (δίς, double; δελφύς, the womb), mammals possessing a double uterus, *e.g.* Marsupialia.

Dimerosomata (δίς, double; μέρος, part; σῶμα, body), an order of Arachnida.

Dimyary (δίς, double; μυών, muscle), bivalve Mollusca with two adductor muscles.

Diœcious (δίς, double; οἶκος, house), with distinct sexes.

Dipnoi (δίς, double; πνοή, breath), an order of Pisces.

Diptera (δίς, double; πτερόν, a wing), an order of Insecta.

Discophora (δίσκος, *a quoit*; φέρω, I bear), a group of *Acalephæ* or Jelly-fish; also an order of Annelida.

Echinococci (ἐχῖνος, a hedgehog; κόκκος, a berry), hydatids; the larval form of tapeworms.

Echinodermata (ἐχῖνος, a hedgehog, δέρμα, skin), sea urchins, a class of Annuloida.

Echinoidea (ἐχῖνος, hedgehog; εἶδος, form), an order of Echinodermata.

Echinorhyncus (ἐχῖνος, hedgehog, ῥύγχος, snout), a genus of Acanthocephala.

Ectocyst (ἐκτὸς, outside; κύστις, bladder), the outer coat of a Polyzoon.

Ectoderm (ἐκτὸς, and δέρμα), the outer covering of Cœlenterata.

Ectosarc (ἐκτὸς, σάρξ, flesh), the outer substance of some Rhizopoda.

Edriophthalmata (ἑδραῖος, sessile; ὀφθαλμός, an eye), sessile-eyed Crustacea.

Elasmobranchia (ἔλασμα, a thin plate; βράγχια, gills), an order of Pisces.

Elytrum (ἔλυτρον, a sheath), the chitinous anterior wings of Coleoptera.

Embryo (ἐν, within; βρύω, I swell), the earliest period at which the young of any animal is recognisable.

Endopodite (ἔνδον, within; πούς, a foot), the inner of the two secondary segments of the limb of a Crustacean.

Entomophaga (ἔντομα, insects; φάγειν, to eat), a group of Marsupialia.

Entomostraca (ἔντομα, insects; ὄστρακον, a shell), a division of Crustacea.

Epencephalon (ἐπί, upon; ἐν, in; κεφαλή, head); the hinder part of the brain, which in man covers over the cerebellum.

Epimera (ἐπί, upon; μῆρον, thigh), lateral pieces of the dorsal arc of the somites of Crustacea.

Epiotic (ἐπί, upon; οὖς, the ear), the upper bone of the auditory capsule.

Epipodite (ἐπί, upon; πούς, foot), an appendage of the basal joint of the limbs of Crustacea.

Errantia (*erro*, I wander), an order of Annelida.

Eurypterida (εὐρύς, broad; πτερόν, a wing), an extinct group of Crustacea.

Exopodite (ἔξω, outside; πούς, a foot), the outer of the two secondary joints of the somite of a Crustacean.

Fissirostres (*findo*, I cleave; *rostrum*, beak), a group of perching birds.

Flagellum (a whip), the appendage of Pilidium and other Protozoa.

Foraminifera (*foramen*, a hole; *fero*, I bear), a division of Protozoa possessing minute perforated shells.

Furculum (a little fork), the merry-thought or clavicle of birds.

Gallinacei (*gallina*, a fowl), the order of Rasores.

Ganoid (γάνος, brightness), applied to certain fish scales.

Gasteropoda (γαστήρ, stomach; ποῦς, foot), a class of Mollusca.

Gephyrea (γέφυρα, a bridge), a group of Annelida.

Gonocalyx (γονός, offspring; κάλυξ, a cup), the swimming bells of Acalephæ.

Gonophore (γονός, and φέρω, I bear), the generative buds of Hydrozoa.

Grallatores (*grallæ*, stilts), wading birds.

Graptolidæ (γράφω, I write; λίθος, a stone), an extinct division of Hydrozoa.

Gymnolæmata (γυμνός, naked; λαιμός, the throat), an order of Polyzoa.

Gymnophiona (γυμνός, naked; ὄφις, snake), an order of Amphibia.

Hæmatocrya (αἷμα, blood; κρύος, cold), the cold-blooded Vertebrates.

Hæmatotherma (αἷμα, blood; θέρμος, warm), the warm-blooded Vertebrates.

Halteres (ἁλτῆρες, from ἅλλομαι, to leap), the representatives of the posterior wings of dipterous insects.

Helminthæ (ἕλμινς, a worm), the intestinal worms.

Hemimetabolic (ἡμι, half; μεταβολή, change), applied to insects that only pass through a partial metamorphosis.

Hemiptera (ἡμι, half; πτερόν, wing), an order of Insecta.

Heterocercal (ἕτερος, diverse; κέρκος, tail), the tail of fishes when the lobes are unequal.

Heterophagi (ἕτερος, diverse; φάγειν, to eat), birds whose young are born in a helpless state.

Heteropoda (ἕτερος, diverse; ποῦς, foot), an order of Mollusca.

Holometabolic (ὅλος, whole; μεταβολή, change), insects whose metamorphosis is complete.

Homocercal (ὁμός, like; κέρκος, tail), term used to describe the tails of fish whose lobes are equal.

Homology (ὁμολογία, agreement), applied to parts which are morphologically or structurally alike.

Hydræcium (ὕδρα, a water-dragon; οἶκος, house). the hollow part of the cœnosarcinto which some of the Calycophoridæ can be retracted.

Hydridæ (ὕδρα, a water-dragon), an order of Hydrozoa.

Hydrosoma (ὕδρα, water dragon; σῶμα, body), the entire organism of any Hydrozoon.

Hydrozoa (ὕδρα, and ζῶον, a creature), a class of Cœlenterata.

Hymenoptera (ὑμήν, a membrane; πτερόν, a wing), an order of Insecta.

Hyoid (Υ-, εἶδος, form), the bone which supports the tongue.

Hyrax (ὕραξ, a shrew, or weasel), one of the Perissodactyla.

Ichthyodorulites (ἰχθύς, a fish; δόρυ, spear; λιθός, stone), the fossil fin spines of Pisces.

Ichthyosaura (ἰχθύς, a fish; σαύρα, lizard), an extinctgenus of Reptilia.

Inoperculata (*in*, without; *operculum*, a lid), a division of Gasteropoda.

Insessores (*insideo*, I sit upon), an order of Aves—the perching-birds.

Isopoda (ἴσος, equal; ποῦς, a foot), an order of Crustacea.

Labium (lip), applied to the lower lip of Annulosa.

Labrum (lip), applied to the upper lip of Annulosa.

Labyrinthodontia (λαβύρινθος, a labyrinth; ὀδοῦς, a tooth), an extinct order of Amphibia.

Læmodipoda (λαιμός, throat; δίς, double; πους, a foot), an order of Crustacea.

Lamellibranchiata (*lamella*, a thin plate; βράγχια, gills), the bivalve Mollusca.

Lamellirostres (*lamella*, dim. of *lamina*, a small plate of metal; *rostrum*, a beak), the group of flat-billed Natatores.

Larva (a mask), the grub or caterpillar, the first step of the insect on emerging from the egg.

Lepidoptera (λεπίς, a scale; πτερόν, a wing), an order of Insecta.

Leptocardia (λεπτός, slender; καρδία, heart), an order of Pisces, often called Pharyngobranchii.

Lepidosiren (λεπίς, a scale; σειρήν, a mermaid), the mud fish.

Lithocysts (λιθός, a stone; κύστις, a cyst), the sense organs (auditory ?) of certain jelly-fish.

Longipennata (*longus*, long; *penna*, wing), a group of Natatores.

Longirostres (*longus*, long; *rostrum*, beak), a group of Grallatores.

Lophophore (λόφος, a crest; φέρω, I bear), the oral disc of Polyzoa on which the tentacles are borne.

Lophyropoda (λόφουρος, having stiff hairs; πους, a foot), an order of Crustacea.

Lorica (a breast-plate), the protective case of certain Infusoria.

Lucernarida (*lucerna*, a lamp), an order of Hydrozoa.

Macrodactyli (μακρός, long; δάκτυλος, finger), a group of Grallatores.

Macrura (μακρός, long; οὐρά, a tail), a genus of decapod Crustaceans.

Malacostraca (μαλακός, soft; ὄστρακον, shell), the soft-shelled Crustacea.

Mallophaga (μαλλός, a fleece; φάγειν, to eat), an order of Insecta.

Mandible (*mandibulum*, a jaw; fr. *mando*, I chew), the upper jaw of Insecta; the lower jaw of Vertebrata.

Marsipobranchii (μάρσιπος, or μάρσυπος, a pouch; βράγχια, gills), an order of Pisces.

Marsupialia (μάρσυπος, a pouch), an order of Mammalia.

Maxillipedes (*maxilla*, jaw; *pes*, foot), the foot jaws of Annulosa.

Merostomata (μηρός, thigh; στόμα, mouth), an order of Crustacea.

Mesencephalon (μέσος, middle; ἐγκέφαλος, brain), the middle part of the brain, applied to the third pair of cerebral lobes, homologues of the optic lobes of man.

Monads (μονὰς, unity), microscopic organisms.

Monodelphia (μόνος, single; δελφύς, womb), a division of Vertebrata.

Monœcius (μόνος, single; οἶκος, house), applied to animals in whom the two sexes are united in one individual.

Monomyary (μόνος, single; μυών, muscle), bivalve Mollusca, whose shells have one adductor muscle.

Monophyodont (μόνος, single; φύω, I generate; ὀδούς, a tooth), Mammals in whom only one (milk) set of teeth is developed.

Monotremata (μόνος, single; τρῆμα, fr. τρέω, to bore; an obsolete pres.; an order of Mammalia, having a cloaca common to the urinary and generative organs.

Myriapoda (μυρίος, numerous; πους, foot), a class of Annulosa.

Natatores (*nare*, to swim), an order of Aves.

Nectocalyx (νηκτός, fr. νήχω, I swim; κάλυξ, a cup), the swimming-bell of jelly-fish.

Nematelmia (νῆμα, thread; ἕλμινς, worm), a division of Scolecida.

Nematocysts (νῆμα, thread; κύστις,

a sac), the 'thread cells' of Cœlenterata.

Nematoidea (νῆμα, thread; εἶδος, form), an order of Scolecida.

Nemertida (νημερτής, 'unerring'), a group of Turbellaria.

Neuropodium (νεῦρον, cord: πούς, foot), the 'ventral oar' of Annelida.

Neuroptera (νεῦρον, cord; πτερόν, wing), an order of Insecta.

Notobranchiata (νῶτος, back; βράγχια, gills), a division of Annelida.

Notochord (νῶτος, back; χορδή, string), or *chorda dorsalis*, a cellular embryonic cylinder placed immediately beneath the primitive groove of Vertebrata, and generally replaced by the spinal column.

Notopodium (νῶτος, back; πούς, foot), the 'dorsal oar' of Annelida.

Nudibranchiata (*nudus*, naked; βράγχια, gills), an order of Gasteropoda.

Octopoda (ὀκτώ, eight; πούς, foot), a group of Cephalopoda.

Odontoceti (ὀδούς, tooth; κῆτος, whale), the toothed whales.

Odontophore (ὀδούς, tooth; φέρω, I bear), the tongue of certain Mollusca.

Oligochæta (ὀλίγος, few; χαίτη, hair), an order of Annelida.

Ophidia (ὄφισα, snake), an order of Reptilia.

Ophiomorpha (ὄφις, a snake; μορφή, shape), an order of Amphibia.

Ophiura (ὄφις, a snake; οὐρά, tail), an order of Echinodermata.

Opisthotic (ὄπισθεν, behind; οὖς, the ear), the posterior part of the bony capsule of the ear.

Opisthocœlous (ὄπισθεν, behind; κοῖλος, hollow), vertebræ with bodies which are concave behind.

Ornithodelphia (ὄρνις, a bird; δελφύς, womb), a division of Mammalia.

Orthoptera (ὀρθός, straight; πτερόν, wing), an order of Insecta.

Ostracoda (ὄστρακον, a shell), an order of Crustacea.

Otoliths (οὖς, ear; λίθος, a stone), little calcareous particles found in the ear.

Oxyuris (ὀξύς, sharp; οὐρά, tail), one of the threadworms.

Pachydermata (παχύς, thick; δέρμα, skin), an order of Mammalia now called Perissodactyla.

Palliobranchiata (*pallium*, mantle; βράγχια, gills), or Brachiopoda, an order of Molluscoida.

Palpi (*palpo*, I touch), processes developed from the oral appendages of certain Annulosa.

Parapodia (παρά, besides; πούς, foot), the 'foot tubercles' of Annelida.

Parthenogenesis (παρθένος, virgin; γένεσις, generation), term used to indicate the reproduction of animals from virgin females by ova without the intervention of a male; otherwise called 'asexual reproduction.'

Patagium (the border of a dress), the 'wing' of bats, &c.

Pedicellariæ (*pedicellus*, a louse), little forceps-like apperdages found on the surface of certain Echinodermata.

Pedipalpi (*pes*, foot; *palpo*, I touch), an order of Arachnida.

Perennibranchiata (*perennis*, perpetual; βράγχια, gills), an order of Amphibia.

Perissodactyla (περισσός, odd; δάκτυλος, finger), an order of Mammalia.

Peristome (περί, about; στόμα, mouth), the space between mouth and calyx. In Actinozoa, the lip of a univalve shell.

Pharyngobranchii (φάρυγξ, pharynx; βράγχια, gills), an order of Pisces.

Phragmacone (φράγμα, enclosure; κῶνος, a cone), part of the shell of a Belemnite.

Phylactolæmata (φυλακτός, guarded; λαιμός, throat), a division of Polyzoa.

Phyllopoda (φύλλον, a leaf; πους, a foot), an order of Crustacea.

Phylum (φύλλον a leaf, sometimes a tree), a term used by Haeckel to signify the genealogical tree of animals.

Physophoridæ (φῦσα, bellows; φέρω, I bear), a family of Hydrozoa.

Phytophagous (φύτον, a plant; φάγειν, to eat), herbivorous animals.

Pinnigrada (*pinna*, a feather; *gradior*, I walk), a group of Carnivora.

Placenta (a cake), the 'after-birth' of Mammalia.

Plagiostomi (πλάγιος, transverse; στόμα, mouth), an order of Pisces.

Planarida (πλάνη, wandering), a division of Turbellaria.

Planula (*planus*, plane), the embryo of Hydrozoa.

Platyelmia (πλάτυς, broad; ἕλμινς, worm), a division of Scolecida.

Plesiosaurus (πλησίος, near; σαύρα, a lizard), an extinct order of Reptilia.

Pluteus (a penthouse), the larval form of Echinoidea.

Pneumatocyst (πνεῦμα, air; κύστις, sac), the float of certain Hydrozoa.

Podophthalmia (πους, foot; ὀφθαλμός, eye), an order of Crustacea.

Podosomata (πους, foot; σῶμα, body), an order of Arachnida.

Polycystina (πολύς, many; κύστις, sac), an order of Protozoa.

Polype (πολύς, many; πους, foot), the separate zoöids of the Cœlenterata.

Polyzoa (πολύς, many; ζῶον, a creature), a class of Molluscoida.

Pressirostres (*pressus*, compressed; *rostrum*, beak), a division of Grallatores.

Procœlous (πρό, before; κοίλος, hollow), a vertebra whose body is concave anteriorly.

Proglottis (προγλωττίς, the tip of the tongue), the generative segment or joint of a tapeworm.

Prosencephalon (πρός, before; ἐγκέφαλος, brain), the front part of the brain, applied to the second pair of cerebral lobes, homologues of the corpora striata of man.

Prosobranchiata (πρόσω, in advance of; βράγχια, gills), a division of Gasteropoda.

Protoplasm (πρῶτος, first; πλάσσω, I mould), the albuminous sarcode which forms the base of all animal tissues.

Protopodite (πρῶτος, first; πους, foot), the basal segment of the limbs of a Crustacean.

Protozoa (πρῶτος, first; ζῶον, animal), the first of the animal sub-kingdoms.

Pseudohæmal (ψευδής, false; αἷμα, blood), the vascular system of Annelida.

Pteropoda (πτερόν, a wing; πους, foot), a class of Mollusca.

Pterosauria (πτερόν, wing; σαύρα, lizard), an extinct order of Reptilia.

Pycnogonida (πυκνός, thick; γόνι, knee), an order of Arachnida.

Raptores (*rapto*, I plunder), an order of Aves.

Rasores (*rado*, I scratch), an order of Aves.

Ratitæ (*ratis*, a raft), one of the three chief divisions of Aves—or birds with unkeeled sterna.

Rhinencephalon (ῥίς, the nose; ἐγκέφαλος, brain), the anterior or olfactory lobes of the brain, which supply the nasal organs.

Rhizopoda (ῥίζα, root; πους, foot), an order of Protozoa.

Rodentia (*rodo*, I gnaw), an order of Mammalia.

Rugosa (*rugosus*, wrinkled), an extinct order of corals.

Ruminantia (*ruminor*, I chew the cud), the cloven-hoofed quadrupeds.

Sarcode (σάρξ, flesh; εἶδος, form), the albuminous basis of animal tissues, a term convertible with protoplasm.

Scansores (*scando*, I climb), an order of Aves.

Scaphognathite (σκαφός, a boat; γνάθος, jaw), an appendage to the mouth of Crustacea, which serves to bale out the water from the branchial chamber.

Scolecida (σκώληξ, a worm), a class of Aunuloida.

Selachia (σέλαχος, a shark), the family of sharks.

Setigerous (*setæ*, bristles; *gero*, I carry), the locomotive organ of Annelida.

Sertularida (*sertum*, a wreath), an order of Hydrozoa.

Siphonostomata (σίφων, syphon; στόμα, mouth), a division of Gasteropoda.

Sirenia (σειρήν, a mermaid), an order of Mammalia.

Solidungula (*solidus*, solid; *ungula*, hoof), the group of Hoofed Quadrupeds.

Steganophthalmata (στεγανός, covered; ὀφθαλμός, eye), the hidden-eyed Medusæ.

Stomapoda (στόμα, mouth; πους, foot), an order of Crustacea.

Strepsiptera (στρέψις, a twist; πτερόν, wing), an order of Insecta.

Strepsirrhina (στρέψις, a twist; ῥίς, the nose), a group of Monkeys.

Strobila (στρόβιλος, a fir cone), the entire adult tapeworm.

Synapticulæ (συνάπτω, I fasten together), the cross bars found in Corallidæ.

Tæniada (*tænia*, a tape), the tapeworms.

Tectibranchiata (*tectus*, covered; βράγχια, gills), a division of Gasteropoda.

Teleostei (τέλειος, perfect; ὄστεον, bone) an order of Pisces.

Telson (τέλσον, the end), the last segment of Crustacea.

Tenuirostres (*tenuis*, slender; *rostrum*, beak), a group of Insessores.

Terricola (*terra*, earth; *colo*, I inhabit), the earthworms.

Tetrabranchiata (τέτρα = τέτορα, a form of the neuter of τέσσαρες, four; βράγχια, gills), an order of Cephalopoda.

Thalassicollida (θαλάσσα, sea; κόλλα, glue), a group of Protozoa.

Thecosomata (θήκη, a sheath; σῶμα, body), a division of Pteropoda.

Thysanura (θύσανος, tassel; οὐρά, tail), an order of Insecta.

Trematoda (τρῆμα, a hole), an order of Scolecida.

Trichocysts (θρίξ, hair; κύστις, sac), peculiar cells found in some Infusoria.

Trichina (τρίχινος, adj. of θρίξ), one of the Nematoid worms.

Trichocephalus (θρίξ, hair; κεφαλή, head), one of the Nematoid worms.

Trichoptera (θρίξ, hair; πτερόν, wing), an order of Insecta.

Trilobita (τρεῖς, three; λοβός, a lobe), an extinct order of Crustacea.

Trochal disk (τροχός a wheel), the oral surface of Rotifera.

Tubicola (*tuba*, a tube; *colo*, I inhabit), an order of Annelida.

Tunicata (*tunica*, a cloak), a class of Molluscoida, now called Ascidioida.

Turbellaria (*turbo*, I disturb), an order of Scolecida.

Umbo (the boss of a shield), the back of a bivalve shell.

Urodela (οὐρά, tail; δῆλος, visible) an order of Amphibia.

Vibracula (*vibro*, I shake), peculiar filamentous appendages found in Polyzoa.

Vibrio (*vibro*, I shake), a minute vegetable organism.

Xiphosura (ξίφος, a sword; οὐρά, tail), an order of Crustacea.

Zoöid (ζῶον, an animal; εἶδος, form), the separate organisms of a compound animal; such as many of the Cœlenterata.

Zygantrum (ζυγόν, a yoke; ἄντρον, a cave), the hollow in the vertebræ of Ophidia, into which fits the zygosphene.

Zygosphene (ζυγόν, a yoke; σφήν, a wedge), the conical projection on the vertebræ of Ophidia, which fits into the zygantrum.

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